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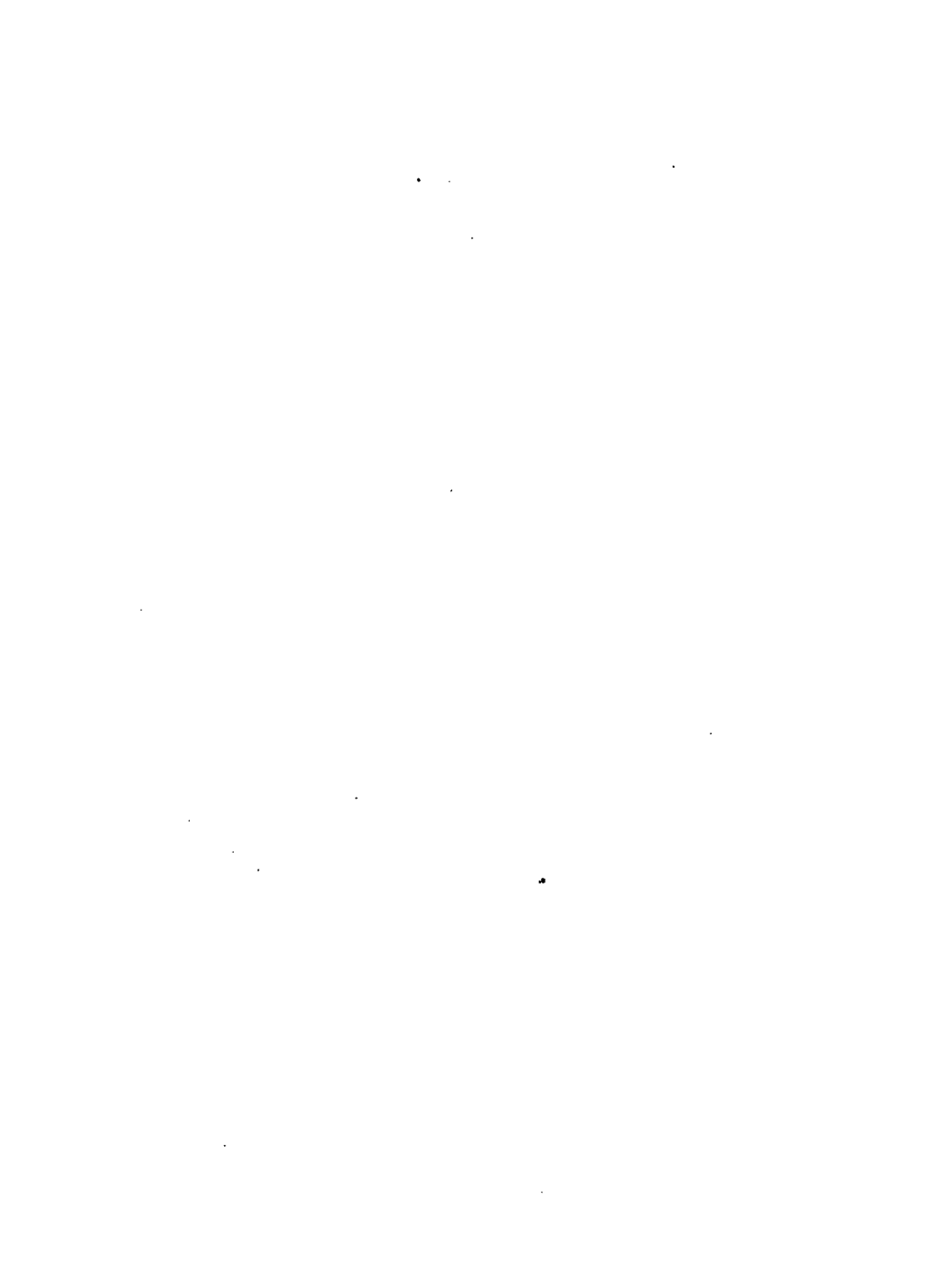
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THE HUMAN BODY
AND ITS FUNCTIONS

H. SINCLAIR PATERSON M.D.





THE HUMAN BODY

AND ITS FUNCTIONS.

A
SECOND COURSE OF LECTURES
DELIVERED IN THE LECTURE HALL

OF THE
Young Men's Christian Association,
165, ALDERSGATE STREET, LONDON,
JANUARY—MARCH, 1880.

BY
H. SINCLAIR PATERSON, M.D.,
Author of "STUDIES IN LIFE."



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TO THE RIGHT HONOURABLE
THE EARL OF SHAFTESBURY, K.G., &c.,
WHO, AMID HIS ABUNDANT LABOURS FOR THE
PROMOTION OF HIGHER INTERESTS,
HAS NEVER IGNORED
THE FUNCTION OF THE BODY.

Lord Shaftesbury had kindly consented to preside at the first Lecture,
but was prevented by the state of his health.

PREFATORY NOTE.

THESE Lectures are simply intended to form an introduction to the study of Physiology. Throughout their delivery I had a twofold purpose in view. While endeavouring to give a fair and moderately ample outline of the contents of physiological science, I sought steadily to awaken such an interest in the subject as might lead to full and protracted study.

The freedom of extempore speech belonging to their first expression has been retained in their publication.

BELGRAVE PRESBYTERIAN CHURCH,

April, 1880.

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I.

THE ORGANISM.

ON the wall of Sir William Hamilton's class-room in the University of Edinburgh this inscription might be read :

"THERE IS NOTHING GREAT ON EARTH BUT MAN.
THERE IS NOTHING GREAT IN MAN BUT MIND."

Now, I doubt not, that among human kind, whatever pleas might be urged in behalf of other beings, there will be the most cordial unanimity in the acceptance of the first statement ; but the latter is now very generally abandoned except by metaphysicians. It is supposed that, after all, the mind is simply another aspect of the body—the outcome of it in one direction—and that when we have exhausted the study of the physical components of man, we have left nothing further to examine.

I need hardly say to those who have listened to the former course of lectures, that I have no sympathy whatever with this doctrine. There is a tendency at the present time to look upon breadth of thought as of

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peculiar value, and, I may add, as having a somewhat peculiar significance. Those who plume themselves on being broad thinkers are in the habit of importing certain forms of thought into all regions which they enter, and imposing them upon every fact that they find there. And that method they consider equivalent to width of study. There are some broad theologians, for example, who are inclined to imagine that all distinctive creeds are equally important or unimportant. Instead of recognising specific facts that have been reached, either in the study of nature, or in the reception of revelation, they endeavour to find out what they call the broadest truths that are accepted everywhere and in all times, and they regard these as being alone substantial and worthy of credit.

It seems to me that these men actually reverse the process on which they lay so much stress in regard to other matters. Evolution is a progress from the homogeneous to the heterogeneous, from the simple to the complex. Consequently progress is inverted if we go back from the complex to the simple. And in the realm of thought many are going back to those elements that are most simple, and ignoring altogether historical advance and additions.

I have no sympathy, on the other hand, with those who are narrow enough to accept only one particular form of teaching, and to despise all others ; and who

are inclined to look with suspicion, if not with dislike, upon all novelty, either in doctrine or practice. I believe that the true method, which we should earnestly cultivate, consists in having the mind open to all facts and all truths, whilst it is, at the same time, void of all prejudice and free from all distortion of vision. We ought to be prepared to recognise the revelation that God gives us in nature or elsewhere simply as it exists, and with utter fearlessness to receive into our creed all that is determined thereby. I am not inclined to argue, as some do, that the soul makes for itself a body. There is a school of philosophy which maintains that each soul organises for itself, as its own habitation, the particular form that is fitted for it; and that we have actually, as framers of all the bodies that exist, certain souls or immaterial principles that fashion and form them according to their needs. But as little am I inclined, on the other hand, to believe that the soul is simply the action, in certain directions, of the body, and that it is not to be distinguished or separated in any sense whatever from that body wherewith it is associated. I recognise both. I recognise mind and material organism. And although I may not be able to understand all their mutual relations, or their mutual actions, I am not, on that account, at liberty to ignore either the one or the other. There are many facts that we are not able to correlate, but our in-

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ability to correlate them or bring them together into harmonious union is no reason for the rejection of either. We must be content to wait until the time comes, if come it may, when we shall see more clearly the mutual connection of these facts. Or, if it does not come, as come it never may, we must be content still to hold to the facts, although we are unable to see in what way it is possible to harmonise them. In philosophy there are what are called antinomies, or antagonistic principles ; but the fact of their being in antagonism has never been held sufficient to negative the evidence on which they individually rest.

I make these remarks, introductory to this course of lectures on "The Human Body," because we shall have to deal mainly throughout with the physical organism. And I would have you remember that in dealing with these material parts of our nature I never for a moment forget that we have given to us more than body. And while I am willing to admit all that can be proved in regard to the body, and to give full weight to every fact that I can learn in connection with it, I am not to be supposed at any time as teaching that the body is everything, or even that it is most important.

We may take the body as the foundation, using that term in the sense which these words suggest : "Our foundation is in the dust." We are related to

other animals very closely by our physical frame. Man is classed among the primates, and among the primates we find also the anthropoid apes, the Simiadae and the Lemuridae.¹ If we compare the structure of man's body with the form of the orang-outang, we find that there are very close resemblances between the two. Of course, I do not forget that there are marked differences between men and monkeys. But for the present our attention is called to these very striking similarities between the two classes. We find that the general outline is somewhat similar, and, if we examine the skeleton, we find that, with certain distinctions, there is still a marked resemblance in the conformation of both.

It may be argued, and has been, as you are aware, that this resemblance proves that there is a genetic connection between men and monkeys. For doubting that assertion I have formerly given several reasons.² I am not prepared to accept it in any sense whatever. But that there is a similarity of plan and physical purpose I admit as freely as any one who contends strongly for the other belief. Men and monkeys are formed very much on the same physical plan, and, so far as physical conditions are concerned, within very much the same range. Even those, however, who insist on the connection that I disavow admit

¹ Huxley's *Introduction to the Classification of Animals*.

² *Studies in Life*, p. 111 et seq.

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that there is a very marked difference between the two classes in matters of mind and of feeling, and also in matters of conduct. And that is indeed all that, from our stand-point, we need for the present to claim and contend. If it were true that the bodies were exactly alike, so that you could not possibly distinguish between the figure of the monkey and the figure of the man, so that you required to come into close contact and personal dealing with either to distinguish which was which; the very fact that man is intelligent; that man has conscience and purpose, would mark out a very broad gulf existing between the two, and would be the best possible proof, even in the absence of every other distinction, that they stood on entirely different platforms.

There was a contention at one time between two very distinguished anatomists in regard to a very small difference that was supposed to exist between the brain of certain apes and the brain of man. I was inclined at that time to argue after this fashion: Suppose that *there were no difference*, that the brains were exactly alike in configuration, in weight, in mass, and in every other particular—that they were so nearly alike that if placed together, and you were not told beforehand that this belonged to the bestial tribe and that to the human, you could not possibly distinguish the one from the other; suppose the likeness was as exact and thorough as it is possible for likeness to be: yet in

the very fact that man is man, rational and responsible, and the monkey is monkey, irrational and irresponsible, you have proof of the fact that God breathed into *man*, and that "the inspiration of the Almighty giveth *him* understanding."

It is possible for us so to study nature that we recognise resemblances everywhere. And it is possible for us, on the other hand, so to study nature that we recognise distinctions everywhere. I believe that there are two classes of mind that part in these different directions. Some are always finding analogies, and others are always discovering dissimilarities. The true state of mind and method that I desire to have and use, and that I would strongly urge all who wish to be well informed earnestly to seek and cultivate, is distinguished by the aptitude to recognise both resemblances and differences, and to give due weight to the one and to the other. Find out similarity where it exists, and note its true significance. Do not be afraid to do that. Find out also difference where it exists, and give it its due significance with the same frank fearlessness. We shall have a much smaller science, and a very much more barren science, if we confine our view either to the one or the other. If we desire to have true science, and make ourselves familiar with all the truths which nature contains, we must be prepared to exercise our judgment all round, and recognise with equal readiness likenesses and unlikenesses.

For the present it is my purpose to recognise likeness, and, as I have already said, I have no hesitation in admitting that man stands on the same platform, so far as his body is concerned, as other animals ; that he belongs to the *Vertebrata*, class *Mammalia*, order *Primates*, or, as some prefer, *Bimana*. He is allied by very definite characteristics to the different apes to which I have alluded. And I am willing to admit, further, that when we examine his body, we find in it processes that are *akin*—I cannot use any other word fairly—to processes that we recognise in the inorganic world outside of us. We find that the laws of the diffusion of fluids and gases, for instance, hold good within man's organism just as they hold good in the realm of nature outside that organism. There are certain physical laws and certain chemical laws that have their place and operation within our body, just as they have in the world without. But to say that these laws operate within us, and to insist that they *alone* operate within us, and operate precisely as in inorganic nature, are two different things. To explain the whole action of man's organism by chemical and physical processes is a very different thing from acknowledging that chemical and physical processes are carried on within man's framework. The latter I readily and frankly admit ; the former I as strenuously deny. And I deny it just on this account : that we find there are peculiar results and peculiar arrange-

ments that differentiate organic life from all other forms of existence whatever ; and that it is impossible for us, without the presence of life, to secure any of the results that are readily enough produced wherever life is in operation. As I said in the former course, "Life" is a term that we must use.¹ It represents the sum of the functions of an animal—any animal that we regard at any particular time. And it alone can be recognised as the producer² of certain distinct effects that we easily perceive—effects that are unknown in any case to follow, except where it is present. We are obliged, if we use any term whatever to help us in the expression of the cause that acts in the production of these effects, to employ some term, and the most intelligible term is that simple word "Life," which we have used already on many occasions, and which is thoroughly adequate to the necessities of the case in the present state of our knowledge.

Man has a very complex organism, and stands, as we commonly say, at the head of the animal creation. If we consider his *structure*; if we study him, as scientists say, morphologically, we find that his *form* is most curiously complete, and thoroughly developed. If we study him, as scientists say, physiologically, that is, if we examine the *functions* that he performs, we find that these also are wondrously varied, and

¹ *Studies in Life*, p. 44.

² *Causa, sine quâ non.*

strangely adapted for the purposes which they are designed to fulfil. Still, if we examine more minutely into the nature of this structure and into the nature of these functions, we must come down to the lowest elements which are employed in building up the complete structure, and to the lowest actions of which these varied functions are the outcome and issue. When we do that we have to deal with what may be called the primary or elemental facts of life. These are very simple, but they are also very mysterious. Something like a speck of floating glue, something that has no definite form, that possesses the power of motion, and that is able to act in each direction apparently according to an impulse of its own, is the ultimate agent employed in building up all organisms—the organism of man as well as the simplest organism that we find floating in any of our wayside pools. What Dr. Lionel Beale has called **BIOPLASM** is the great weaver that forms the tissues of life and that builds up all the different organs in their wondrous complexity. The entire human body is built up by “structureless specks of matter.” It has been said, you are aware, that there is a very suggestive similarity between the action of crystallisation and the action of organisms. From certain solutions in favourable circumstances crystals are deposited, and after these crystals have been formed, if by any accident any part is broken, by introducing the trun-

cated crystal into a proper solution, a part corresponding to that which it lost will be supplied, and it will regain its former completeness. And it has been hinted that, in the formation of crystals and in their reproduction of parts, we have something corresponding closely to the building up of organic beings, the repair of injuries, or the reproduction of lost parts. That there is a resemblance of a very vague sort we need not deny. But there is a marked distinction between the two processes that we can at once recognise as soon as it is stated. The crystal only gains parts by *accretion*, that is to say, by the deposit on its outer surface of one grain after another; but an organism weaves or builds up its structure from within. In the one case you have *addition*, in the other *growth*. And the organism grows by changing *dead* matter into *living* matter. It assimilates it, making it bear its own likeness and perform its own functions. If there is not a wide distinction in that simple fact I do not know where it is possible to find any distinction at all. Wherever we have life, in its simplest forms, we have this mysterious action. It can lay hold of certain materials outside of it that are not living and use them for its own purposes, by endowing them for the time being with its own life, enabling them to take part in its own processes. And whether we have it in the larger organism of man or in the smallest animalcule, we have this function performed that distinguishes,

throughout the whole of nature, the living from the lifeless.

Of course, when we have such a composite organism as in the human being, we have this carried on by a somewhat roundabout process. You are aware that we are continually losing material and continually adding material; yet it would be possible for any one in certain circumstances, from day to day or from week to week, to remain very much the same in weight, even though, in that time, he should pass through his body a very large amount of matter. Our expenditure and our income may be made to balance each other so nearly, that there is no appreciable margin, either on one side or the other. By every word we speak, by every action we perform, in every step we take in walking or running, we are wasting part of our body. When we take food, if it be thereafter properly digested and conveyed in the current of the blood to the different points where it is needed to supply the waste, we have material introduced that takes the place of that which has been spent. In that way we are enabled to preserve our integrity within certain limits. This continuous change is carried on through the whole term of life. I should have mentioned, perhaps, that while inorganic materials are in a state of what may be called stable equilibrium, remaining unchanged if not interfered with, organisms are in a state of unstable equilibrium, they are always

changing. In addition to that they pass through a definite cycle of changes. Each organism—I am speaking now specially of animal organisms—has its own appointed term of life, and during that term of life it passes through certain definite changes. For instance, in the child we have cartilage which in the adult becomes bone. Then in old age, when the limit of life is being reached, we find the cartilaginous or animal element in bone is lessened and that the earthy matter preponderates. The bone becomes more earthy, and consequently more fragile. It is well known that bones broken in childhood are more easily and deftly repaired than in advanced years, and much more easily than bones that are injured or broken in old age. There is a certain definite plane along which a living being moves; and its term of life has a fixed limit. While it continues to move along that plane, there is a continual motion taking place within itself. We are never in one stay for a single hour together. There are those continual processes of waste and repair carried on throughout the whole term of our being. And without any very delicate investigation, or without any very careful study, it is possible for us by means of certain—shall I call them organic—indicators to carry on this work fairly and well. We do not need, as some have done, to calculate the amount of our loss and to weigh out the amount of food we take, so as to balance the one precisely by the other. By means of our appetites and our natural

desires, we can maintain the balance fairly right all through a long life. The whole organism has been so delicately adjusted, that it is able to maintain life without the labour that might at first sight seem necessary in order to avoid excess on the one hand, or loss on the other.

It has been said, you are aware, that the action of man—not only the action of certain animals lower in the scale, but the action of man himself—is what has been termed automatic; that man is an automaton. An automaton is something self-moved, if we are to take the derivation of the term. And I would have no objection to the application of the word if you confine it to its exact significance. But the intention, in maintaining that man is an automaton, is to prove that somehow or other we do not possess that freedom of action and of motion which is necessary in order to responsibility, and which we think is essential to our existence as intelligent and accountable beings. Some statements have been made in certain quarters, that have been considered sufficient to warrant this conclusion.

But I must tell you, before talking of these statements, that the conclusion to which Professor Huxley comes, as formulated in his address at the Belfast meeting of the British Association for the Advancement of Science, is, that “man is a conscious automaton, having free-will in the only intelligible

sense, that is, being able to do as he likes." ¹ This is a very strange outcome of the argument he uses, at all events so it appears at the first blush to ordinary minds, although it has a fuller meaning when it is examined more closely. We talk about Zoe or Psycho, for instance, at the Egyptian Hall, as automata. They are figures so constructed that they act in certain directions. But it would be absurd to suppose that men, or animals of any kind, are figures containing mechanism after that fashion, and wound up or prepared for performing a certain round of actions. There is a broad enough distinction easily recognised between the two classes of things.

But when we say that man is "a *conscious* automaton," we introduce another element, and we take away the strangeness from the first statement. He is self-moved in the sense of mechanism, for, I suppose, that is what is intended to be implied; at least, his motions are based entirely upon physical action and process, though he has all the time a certain consciousness or acquaintance with his own actions, thoughts, and feelings, which consciousness differentiates him from those other automata that are formed and arranged by human skill.

The main illustrations employed in support of this theory are these: Professor Huxley says, if you take a

¹ "On the Hypothesis that Animals are Automaton." *Fortnightly Review*, November, 1874.

frog, cut off its head, and place it on the palm of the hand, it will remain stationary, just as you place it, for a long period of time. Unless stimulated, it will not move. But if you carefully raise the hand so as to bring it to a vertical position, you will find that the frog gradually raises itself and lays hold by its fore limbs of the upper finger, so that it may prevent itself from falling. And if you turn your hand carefully round, it will also go carefully round until it rests quietly on the back of the hand. This, let it be noted, is *unconscious* automatism. The brain has been taken away, the organ which is supposed consciously to give direction to the muscles has been removed; and yet, without that means of becoming acquainted with danger, and without that means of taking precaution against the danger, it carefully preserves itself in the turning round of the hand.

I do not suppose that there is any unwillingness among physiologists to acknowledge that there are certain functions automatic in that sense. I suppose there are many physiologists who would admit that many of the instincts of the lower creatures are automatic, and that many of our own actions, which may have been conscious in the first instance, become automatic. That is to say, after we have acquired by habit certain modes of operation, we perform them without being conscious of our action at the time. It is a rather difficult task to learn to walk.

We have forgotten all about it ; but children find it a hard thing to keep an upright position, and to advance on two limbs only without falling. Those who have learned to skate know that the acquirement has not been without its difficulties and dangers. But the child has a much more difficult task to perform in acquiring the habit of walking. And yet we now daily walk in any direction without any consciousness of effort ; all the muscles are called into play as they are needed, so that we balance ourselves and advance one foot after the other without any thought or care. Walking has become, in a sense, automatic ; we do it without thinking about it. Somehow the nervous action seems to run in the accustomed groove, the muscles seem to be called into play as they are needed without our attention being called to this one or to that. A great many actions can be performed in the same way very swiftly and easily as, for instance, playing an elaborate piece of music on the piano, or keeping up in the air four or five balls at one time. When we have acquired facility of execution, these things are done without any consciousness of effort, though there was a very large amount of conscious effort expended in learning. But this does not at all affect the fact that there are many other actions that are performed directly by a conscious and immediate effort. We resolve to walk to the right or to the left, and our limbs obey. If we do

not wish to go further in one direction, we diverge, or retrace our steps. We can interfere at any moment by bringing thought and purpose to bear on our progress. There are actions in the body that are carried on apart from consciousness altogether. The beating of the heart goes on when we are sleeping as well as when we are awake. We can interfere with the action of the lungs to some extent by holding our breath, or by taking a deep breath, and we modify the emission of air in speech ; but, on the whole, this action is an independent one. But the fact that some actions are automatic, and that others may become so, does not prove that all actions are automatic. Admitting that in certain instances, such as that of the *headless* frog, there may be the possibility of certain actions being done in this way—and there is nothing startling in these actions to physiologists—there is, above and beyond them, the fact that *beings with heads* have a certain, direct, intelligent power to change their action in this direction or in that ; and they can purposely interfere, to a great extent, even with some automatic actions themselves, and this *facultas* is higher and ampler than these other aptitudes of action which have been described.¹

Professor Huxley quotes a very interesting pathological history in the course of his argument. A

¹ For further details consult subsequent lecture on "The Nervous System."

French soldier at the battle of Bazeilles, some years ago, was wounded by a bullet, which fractured one of the bones of the skull (the parietal), producing paralysis of the right side of his body. For about a year he remained in this condition. Within four months after the infliction of the injury he became subject to periodical brain-disturbances. These aberrations continued from fifteen to thirty hours, the interval between the times of their recurrence varying from fifteen to thirty days. During his lucid time he attended conscientiously to his duties as an attendant in the hospital. He was patient, obliging, and willing to help in everything. But suddenly, and without any warning to the bystander, he would pass into another condition, in which he seemed to be altogether unconscious. He could move about and smoke a cigarette; but he would smoke hay made up in the usual form as pleasantly as tobacco, seemingly unaware of the difference. He would drink a glass of vinegar or a solution of quinine as readily as water. He ate, drank, walked, smoked, rose and went to bed at his accustomed hours; but all the time, pins, etc., might be run into his body without producing any indication of pain.

The full details of the case you can read in Professor Huxley's paper in *The Fortnightly Review* for November, 1874. It is evidently adduced as an illustration of Automatism. I do not question the

facts observed, however strange they seem ; I only contend that they do not prove that men are automata. Was he an automaton during the twenty-seven days of his normal conscious life ? It seems to me that the illustration has another side altogether that is strangely overlooked, and that instead of proving the theory in support of which it is adduced, it is a fairly available argument against it. In his deranged condition the man's actions are automatic ; but, then, this is a lower and lesser form of life. There is another state, and that the natural one, in which the man is able intelligently, purposely, and voluntarily to direct his actions and to control his movements. This is shown with special emphasis by a circumstance in the record, to which allusion is made by Professor Huxley in a foot-note. When the man was in his natural or normal state, he was, as has been said, very obliging and honest ; but in the automatic condition he *was ready to steal anything on which he could lay his hands*¹. I think this goes very far to establish the fact that man is something more than an automaton, something more even than a conscious automaton. For if any one is prepared to contend—and the contention is admissible—that this man during his automatic condition had his con-

¹ *British Medical Journal*, August 24, 1874. Quoted by Dr. Elam in article on "Automatism and Evolution" in *Contemporary Review*, October, 1876.

stitutional feelings and wishes brought into play, and that he was consequently ingrainedly a thief, then he must have been able to exercise a very strong volitional control when restored to his rational and fuller life, so that he laid his hands on nothing that did not belong to him!

But I daresay you noticed there was added to the statement, "Man is a conscious automaton," this further statement: "Having free-will in the only intelligible sense, being able to do exactly what he likes." Now of course Professor Huxley is aware that these words do not touch the controversy that exists between the advocates of free-will and the advocates of necessity. I do not think that the most determined advocate of necessity would refuse to admit that men everywhere are able to do what they like, that is to say, within the limits of the possible. Men everywhere can do what they *like*. The phrase is ambiguous, and avoids, if it does not conceal, the real problem. What we have to determine is, the possibility of changing the "liking," and, if it can be changed, the method by which this result can be reached.

These are the philosophical questions to be discussed, and the answer lies outside the range of Automatism. The influence and arguments of our fellow-men tell upon our actions, and, I venture to add, the influence and arguments of God, which we sum up in the expression "Divine Grace" form a most influ-

ential factor, accredited alike by history and experience. For our present purpose, however, it suffices to remember that we are not *driven* either by fatal or favourable necessity; that we have "choice" in our own power, as intelligences "looking before and after," absolutely and entirely; and that we have a corresponding sense of responsibility in choosing the right and refusing the wrong, or in doing the wrong while distinctly rejecting the right. That consciousness cannot be overborne. It belongs to us as men and women universally, and it is as valid a fact as any fact that we can find in material nature or in our physical organism.

I am afraid that I might take up too much time by dealing with this subject further. Before closing, let me say a few words in regard to the human organism generally. Looking at man as he appears, we can divide his physical structure superficially into three parts—the head, the trunk, and the limbs. The head contains the brain; the trunk contains the lungs, the heart, the liver, the stomach and other organs; the limbs are used for locomotion or purposes of prehension. If we look at the skeleton [pointing to one] we notice a bony framework which incloses the brain and other parts of the nervous system; and a bony framework enclosing the organs that are especially employed in the maintainence of the animal life. If you look at the skeleton placed sideways, you will find we have a

double tube, one of small calibre behind, and one of very large calibre in front.

In that posterior tube (the spinal cavity) which we can follow right up into the skull, we find the spinal marrow flowering at its summit into the brain. In the larger tube or cavity, we find what may be distinctively called the parts concerned with organic life. I believe that in these two we have representations given in a very broad sense of (1) the organism of animal life, and (2) the organism employed mainly in what we may call directive and rational life.



II.

THE TISSUES; THEIR STRUCTURE AND VARIETY.

IN the story of the exodus from Egypt, we read that when Moses and Aaron stood before Pharoah, Aaron cast down his rod and it became a serpent. The magicians of Egypt did the same thing by their enchantments, but Aaron's rod swallowed up the others. Thereafter, by the stretching out of the same rod, the waters of the Nile became blood ; but the Egyptians also contrived to produce the same results. Then frogs were brought up over the land, and that marvel was imitated, in like manner. But, curiously enough, when the next miracle was wrought, the enchanters of Egypt confessed that they were unable to do likewise, and they acknowledged that therein was the finger of God.

Now, I venture to say, that it is possible to produce a colourable imitation of some of the results of life. To a certain extent, the chemist in his laboratory can imitate the processes, or, at all events, the results of the processes that are carried on in the living organism.

But there is a certain terminus reached beyond which it is impossible for him to go. It has been said by a very celebrated writer, that the gulf or gap between the organic and inorganic—the chasm yawning between the two—is being rapidly filled up.¹ If he had said that the bridge between the living and the non-living was being formed, his statement would have been much more startling, and would have evoked from biologists a readier denial. But even accepting the terms which he employs, we find that there is no relationship being established in reality between the two kingdoms in nature—the organic and the inorganic. *Nothing that takes part in any living process within the body* has ever yet been imitated by any of the arts or skill of the chemist. There are certain *organic products*, we acknowledge, that have been formed by chemical methods; but it has been hitherto found impossible to imitate muscular tissue even as it lies dead on the dissecting-table. Chemistry cannot even produce anything corresponding to the albuminous products given to us so widely and freely by the vegetable kingdom. As I said on a former occasion,² if it were possible to do this, then we could have unlimited supplies of food produced, notwithstanding the inclemency of the skies or the adverseness of seasonal conditions. But it is well and widely known, that no

¹ Herbert Spencer's *Essays*. Vol. iii. p. 237.

² *Studies in Life*.

artificial process yet known to chemistry can enable us to cross this boundary, or to produce even fit substitutes for the simplest products of that *vegetal organic life* on which we depend for nutriment and growth. No chemistry can originate life; it cannot even produce the material in a *lifeless* form that has once taken part in a living process, much less the living material with its own peculiar action.

And yet we are accustomed to hear a great deal at the present time about the *mechanism* of the human body. It is quite fashionable to compare this wonderful structure of ours to a nicely-constructed and well-ordered machine. Evidently the purpose of this comparison is to suggest that we are under the same physical laws as other mechanisms, and that, to a great extent, if not altogether, the terms that are used in speaking of mechanisms external to us can be employed in describing our own bodily organism. I have no objection to the term "mechanism" or the word "machine," provided we clearly understand that we are using metaphorical language; and provided there be no intention of suggesting that there is a full comparison or relationship between the two. Such language is allowable if we remember that, though in some respects the body is like a machine, in other respects, it is altogether opposite and unlike. For purposes of comparison and for helping our conception of what is done within the body, we may speak

of it in connection with these resemblances, not, for a moment, forgetting the real permanent differences.

For instance, I may compare my watch and its mechanism to the human body, with its *vital* arrangements. Taking a very superficial view of the matter, I might say, just as I find that these elements enter into the composition of the human body—hydrogen, oxygen, nitrogen, and carbon, and some other fifteen not so widely used—so I discover that there are certain elements that enter into the composition of the watch. I find brass, iron, carbon (in the shape of diamonds), silicon (in the glass), and other elements. All these are combined to form this machine that we call a watch. Looking at it I find there is a seconds-hand that moves very apparently. There is a minute-hand and an hour-hand that move comparatively slowly. If I listen to it I find it emits sound. If I open it I find there is motion going on in different directions, conditioned by the wheels that are enclosed within the case. In all these respects it has a certain relation of a very superficial character to the human body. That too is made up of chemical elements, to a large extent, just as this watch is. It emits sounds as I speak. It moves as I lift my hand or walk. It has certain processes carried on within it, that can sometimes be seen through the walls of the chest, as in the beating of the heart ; and other motions that are visible, as in the turning of the eye from one direction

to the other, or in the movement of the muscles. In these, and many other respects, there is a distinctly observable comparison fairly instituted between the bodily mechanism and this small piece of mechanism—a watch.

But did you ever know or hear of a watch that grew, or that put itself together, forming all its parts from other constituents existing and widely scattered in nature? Did you ever know or hear of a watch that originated from microscopic particles of matter, and gathered to itself the brass, iron, silicon, and carbon, and formed its wheels, its spring, its case, and its glass, so that it was fairly adapted, in course of time, for marking the hours and serving its own peculiar purposes? Did you ever know a watch that could repair itself if it became injured, and that produced wheels to take the place of wheels that were lost, or even teeth in the wheels to take the place of teeth that were worn away? Or that could repair any part of the outer covering, the glass, when it was cracked or broken, so that it became whole again as it was at first? Did you ever know or hear of a watch that could give origin to other little watches like itself, or in any other way continue the kind of mechanism indefinitely throughout a lengthened period of time? Did you ever know or hear of a watch without a maker, without some one who collected these different materials, and by his skill and knowledge and purpose arranged them in their definite

collocation for the marking of time, and for all the uses which he intended such a mechanism should serve? And I venture to ask, after making these inquiries, Are there not more differences between the mechanism and the organism than there are resemblances? And are not the differences deeper and more important, by a great deal, than are the resemblances? Then why is it that we are continually being reminded nowadays of the resemblances, while the differences are ignored altogether? Why do certain scientists insist, over and over again, that in certain respects—which nobody denies or doubts—there is a comparison fairly to be instituted between machines or mechanisms and the human body? Why, when doing so, are they not equally careful to remind us that there are differences, thoroughgoing and essential differences, that mark out the two things as wholly and for ever distinct?

I have suggested the reason, and you do not need to read many books to find that it is borne out by the arguments that are raised on these resemblances. These scientists are very anxious to induce us to believe that there is no such thing as a specifically distinct organic kingdom at all. That everything that exists in the human body—brain, mind, and heart—are all within the domain of physical law ; and that we are

* A full statement of essential differences between "Organisms and Machines" will be found in Lewes's *Physical Basis of Mind*, p. 59. *et seq.*

not, in any important respect, differentiated in kind and character from the mechanisms wherewith we are surrounded. I am confident that no one who studies this matter with any care, or with any intention of grasping the truth, can be misled by this fallacious method of statement. When we examine the two things honestly, and when we look at them all round, we find marked distinctions between the two things—mechanisms and organisms—that are immensely greater than any obtrusive superficial resemblances that are apparent to the eye of the mere casual observer.

We know that a little germ of apparently structureless, jelly-like matter becomes in process of time a human body, with all its parts and functions. Now, there is contained in that simple fact a mystery of the most profound sort. This germ is able, somehow or other, to gather from all nature with which it is brought into contact in successive times, the very materials that are required for building up this complete framework, and for performing, through a definite period, all the actions that are peculiar to the human race.

And when we look at the fully formed human body, and examine into the processes that are carried on there, we find the same mystery meeting us still. Did you ever think of the varied combinations that take place in a garden where you have roses, cabbages, apple trees, peach trees, plum trees, and a great many other vegetables and trees of different kinds growing

together? You have all these varieties of vegetable life produced from the same soil, heated and lighted by the same sun, and watered by the same clouds. How is it that in one case we get the plum, in another case the apple, in another the beautiful rosebud or the full-blown rose? How is it that from the same materials, without any alteration in the slightest degree, so far as environment is concerned, we have such a vast difference in the results? Simply because each one has got the power of using these materials according to its own nature, according to its own capacity and skill—if you will allow me to use the expression—for receiving and building up, after a definite plan peculiar to itself, the various forces and substances that are common to all.

We find the same faculty and facility exhibited within the human body. All the tissues, all the membranes, all the organs and parts of every sort, are formed from one fluid, the blood, circulated throughout the organism by the heart. From this fluid, sometimes called “the material of life,” or “the pabulum vitae,” all the different parts of the body, every special organ, each distinct membrane and tissue receives what it requires. The lungs receive from it lung tissue; the liver, liver tissue; the heart, heart tissue; the brain, brain tissue. All these different organs form their own particular substance from this one fluid that bathes them all. It has been frequently said that each tissue or membrane or organ

possesses a specific power of selecting from the blood the material it requires.¹ The blood containing the elements that are requisite for the upbuilding of the body, these tissues, membranes, and organs are supposed, individually, to have the power of choosing and appropriating, each one for itself, the particular elements required for its well-being and work. More recently, however, we learn from microscopic examination, long continued and very thorough, that such language does not adequately represent the facts.

“A mass of bioplasm exposed to certain special conditions which differ as regards heat, moisture, pabulum, and which vary with every kind of bioplasm, grows, divides, and subdivides into multitudes of masses. Each of these grows and subdivides in the same manner until vast numbers result. By these apparently similar masses of bioplasm, different tissues, organs, and members are formed. Some give rise to tubes which carry the nutrient fluid to all parts of the body. Some are concerned in taking oxygen from the atmosphere and giving up carbonic acid to it. Others separate materials resulting from decay, and

¹ Sir James Paget discusses, in a most interesting and suggestive manner, a principle, the germ of which he finds in the following sentence from Treviranus: “Each single part of the body in respect to its nutrition stands to the whole body in the relation of an excreted substance.” Sir James finds in this a philosophical explanation of “permanently rudimental organs,” etc., which evolutionists have so confidently adduced as inexplicable, except by their theory.—*Paget's Lectures on Surgical Pathology*, p. 17, *et seq.* Ed. 1863.

convert these into substances which can be easily removed altogether from the body. Other collections of bioplasm give rise to bone, to nerve, to muscle, and other tissues; while from others, organs so delicate as the eye and the ear proceed by gradual process of development, and convince us of the marvellous and inexplicable powers possessed by the formless bioplasm, by which alone any of them could be formed.”¹

Instead of these different tissues each doing its own differentiated work itself, this structureless, clear, jelly-like substance, called bioplasm,² is continually active in all the different parts of the body, like an invisible workman, building up various tissues and carrying out all the vital processes of the body throughout the term of its existence. This substance that we call bioplasm, or rather these strange activities that we may call bioplasts—little structureless specks of clear, jelly-like matter, are able, I cannot tell you how, to build up a lung, or a heart, or a liver, or a brain. They are able, from their pabulum, which we call food, transformed, not without their presence and co-operation, into blood, to construct all the different parts of this multiple and marvellous organism. Aye, and not only that, but to break down and send away such matter as may be no longer required for the use of the body; to use up such materials as, having been

¹ *Bioplasm*. By Lionel S. Beale, M.B., F.R.S., p. 13.

² See *Studies in Life*, pp. 40, 41.

formed into tissues, can be employed now to better purpose in maintaining the heat of the body, or in doing its work.

There are many varieties of tissue noted in ordinary descriptions of the human body. We may, however, conveniently class them as connective tissues, muscular tissues, and nervous tissues. Still, in order to have a wider view of the subject, we may look at such as we find, for instance, in making a section of the arm. If I were to cut through the arm of a dead body, we would find in the first instance that the knife, passing by any hairs that might be growing on the surface, would divide the integument or skin. The thin film on the surface we find to be lifeless ; it is non-sensitive, like the outer rim of the nails. The hairs on our head, as we all know, can be cut without pain, although at the base or roots they are living and growing, and you may soon perceive that there is sensation if you pull them, or attempt to extract any number conjointly. So in this outer part of the skin we have a superficial layer of dead material that can be separated from the body without any suffering. Indeed, to speak correctly, it has been already thrown off.

Then cutting still deeper, penetrating the true skin, which is highly sensitive, we meet with a filmy-looking substance containing fatty matter in varying quantities, which is really connective tissue enclosing fat cells, though from its contents it is commonly called

adipose tissue. This gives roundness or symmetry to the arms. Going still deeper we come to the red mass, familiarly known to us as the "lean" of meat, or, more accurately, as muscle. We find certain vessels traversing this fleshy mass, having a distinct structure and office, as channels for the blood in its outward or inward flow. We find also in their neighbourhood certain glistening cords that we call nerves. Going still deeper we come to the bone. This is hard and difficult to cut. On sawing through it we find in its centre more fatty matter or adipose tissue, commonly called marrow.

All these different tissues we find in a section of the forearm: the integument, or skin on the surface; the connective adipose tissue; muscular tissue; vascular tissue, or the tissue of the vessels; nervous tissue (nerve cords); osseous tissue, the tissue of the bones; and again adipose tissue, or the tissue of the marrow contained within the bone. Again: if I direct my attention to the trunk, or torso, I find within it a peculiar tissue that we may call lung tissue, adapted for certain reactions between the air and the blood. Then I find the heart composed of muscular tissue, with some structural additions, constituting it a live force-pump for the circulation of the blood throughout the body. I find the liver also there with its special glandular structure—*i.e.*, containing certain glands, or organs of secretion. These glands, or secreting organs, perform

different functions, on which I do not now dwell. We have all these and other organs, membranes, or tissues within the trunk, or torso. And it is somewhat confusing—allow me to remark—at least for the young student, to be obliged to examine them in detail and in their different relations. For practical purposes, and especially for the accomplishment of my design in these lectures, it is sufficient to class them generally, which we may do fairly, as connective tissue, muscular tissue, and nervous tissue. Connective tissue used to be called cellular tissue. It was regarded as the *basis* of all the others. It was said that in it were deposited all the elements required to form the distinct tissues of every sort: nerve matter deposited in the connective tissue to form nervous tissue, muscular matter to form muscular tissue, and so on. We know now that this is not the exact representation; nevertheless, connective tissue is found pervading the whole organism, entering into every part minutely, so that if it were possible to remove from the human body every particle of every other kind of tissue, and leave only the connective tissue remaining, we would have a perfect outline in every detail of the human body. The connective tissue forms what we may call, in a real sense, the foundation or *substratum* of the whole organism. We find it in bone; where, in addition to this tissue, which in itself is comparatively light, we have earthy material deposited to give solidity. We find it in the

teeth ; and in them it is associated with what is called "dentine," to give the specific hardness that they require for the performance of their functions. We find it in every part of the body. And it is all built up by these simple, structureless, clear, jelly-like particles that I have spoken of as bioplasts. And it is maintained in its completeness by their continuous unrelenting action. There is not a particle of the human body, 1-250th part of an inch in diameter, that has not within it one or more of these bioplasts. You cannot find 1-250th part of an inch in the whole frame in which this living action is not carried on by these strange, simple bodies. We find within the body what we may call nutriment on one side, and formed tissue on the other, and, between the two, the bioplasts. And there is no passage from this one form of nutriment to that other form of tissue except through the bioplasts. Given all the nutriment, there is no created power in the universe that can change it into living tissue otherwise than by its translation into this bioplastic condition, and its becoming for a definite period of time alive with that life. You may have all the elements that are required for forming any tissue, but it is impossible to prepare that tissue out of these elements unless they first assume this particular bioplastic form.

The importance of this *living* matter cannot be overlooked, if you remember that it takes part in all the processes of life, and that it is required wherever there

is any living action to be performed, or any living thing to be maintained in its vigour and readiness for work. We cannot explain its action. We find it impossible to tell how it is that this simple living matter is able to perform this kind of work. But we know that so it is, and that it is only where these bioplasts are in activity that life continues. If it were possible to cut them off from their supplies, of course they would die. Or if we could kill them, then, though supplies were given, these supplies could not be assimilated; growth, development, and action would cease. All life depends on the action of these bioplasts in transforming the nutrient materials with which they are daily supplied, first into bioplasts, and then into formed tissue.

Muscular tissue differs markedly from connective tissue. We find in the muscles a great many fibres running in definite directions. These directions are determined by the position which the muscle occupies and the use to which it is to be applied. Many muscles, in addition to this arrangement of fibres in the line of action, have these fibres marked by what are called "striæ;" that is, they are crossed by lines that give them a *striped* appearance. It has been noted that muscles under the control of the will are thus striped or crossed, while muscles not under such control have simply the parallel fibres without any such transverse marking. There is, however, one im-

portant exception. We find that the muscular tissue of the heart is striped or crossed, although we are unable to control its working by voluntary effort as we control the striped muscles that move the arms or legs.

The precise meaning of these stripes in voluntary muscles has not yet been ascertained. The function of muscular tissue is well known, and its action can be stated in a very few words. The muscle that is required for bringing any part of the body into position contracts ; that is to say, its fibres become shortened and broadened. We consequently speak of muscular tissue as possessing the property of "contractility." It is able to move in the two directions I have indicated, and this shortening and broadening of the fibres bring together such parts of the body as we desire thus to approximate. This power belongs to the muscular fibre wherever we find it, and it is communicated to it somehow or other by these bioplasts of which I have spoken.

When we examine nervous tissue, we find that it presents two appearances. Some portions are reddish-grey, such as the outer layer forming the convolutions or foldings of the brain ; while other portions are white, such as the inner part of the same brain, and the cords, or nerves proper, that connect the centres with the circumference. These two kinds of nervous matter form, however, one whole system, which is adapted for

the reception and transmission of various sorts of messages. I cannot enter into a discussion either of the muscular system or the nervous mechanism at this stage. I am talking merely about the marked peculiarities that belong to these different parts, and wishing to draw your attention to the formation of them as depending on this action of bioplasm or living material. In the muscular system we have the power of contracting, and in the nervous system the power of receiving messages from, and conveying messages to, the different parts of the body. These two are sufficiently distinct, and they are also sufficiently separable from the connective tissue.

In order to give a little fuller explanation of one of these tissues, I have before me here two preparations of bone. I have not prepared them myself, so that I cannot tell whether they correspond to my requirements. But I asked that one of the bones might be calcined, so that the gelatinous matter—the animal matter—might be burnt up, and only the earthy matter left behind. If this has been properly done, the bone breaks easily right across. (Breaks the bone.) You cannot thus break the bone in which you have animal matter and earthy matter properly mixed. As we get older our bones have more earthy matter deposited, and consequently become more fragile or liable to be broken. Young bones are more likely to bend. This other bone has been steeped in hydrochloric or muri-

atic acid, in order that the earthy matter might be dissolved, and the gelatinous or animal matter alone left, which is so soft that if we have the bone properly prepared we can actually tie it into a knot (tying it), the earthy matter, which gives hardness, being entirely removed. In young children we have one-fourth of earthy matter and three-fourths of animal matter ; in adults we have four-fifths of earthy matter ; in old age we have seven-eighths. That represents the pliability and frangibility of the bone in each case respectively.

Now all this is accomplished, this adaptation of structural connective tissue for the different ages and for its different purposes and requirements, by the action of these bioplasts, these structureless, formless particles of jelly-like substances that we find existing in the body. We have a representation of them, as many of you know, in the *amæba*. As we examine this simple organism under the microscope, we notice that it sometimes shoots out what we would call a finger, technically called a *process* ; sometimes it shoots out five or six of such processes. We notice also that it assumes irregular shapes, and moves from one point to another. It is able to lay hold of the nutrient material in the surrounding liquid ; and when it has served its own purposes, and taken from it what it wants, it simply disconnects itself from the remainder, and floats away. In that condition it grows and multiplies. We find a similar action performed by these bioplasts within the body.

They are thus able to avail themselves of the materials that are supplied to them, and to form from them the various animal tissues. What a variety we find of these tissues when we examine the body throughout—tissues devoted to different purposes, and subserving a great many ends, and tissues in all variety of circumstances. The skin, for instance, in the palm of the hand becomes hardened in those that perform much manual labour, and thus becomes a protection to other delicate tissues lying beneath. The soles of the feet in like circumstances become hardened. This is particularly noticeable in the case of the Arabs who traverse sandy deserts: and we find a special provision made in the feet of the camel, fitting this animal, without inconvenience, for its long and toilsome journeys over the burning sands. So that, when it is needed, these tissues are not only adapted for the performance of their more general functions; they are furthermore fitted in exceptional circumstances to meet the necessities of individual life.

And all this fitness, general and special, is secured by the action of these bioplasts! And you cannot distinguish the bioplasts that form muscle from the bioplasts that form nerve; you cannot distinguish the bioplasts that form bones from the bioplasts that form skin or muscle. They are all identical in every ascertainable characteristic. Yet these jelly-like particles possess these wonderful capacities and energies, and

are competent to build up and maintain all the different parts of the body throughout our whole life. Nay, more than that, they seem to have what I may venture metaphorically to call their own individual instincts and capacities. For if we take from the film that covers the bone (periosteum) and that is concerned with its nourishment—if we take a fragment of this and graft it on the skin, by a special process with which physiologists are acquainted, we find that this little bit of bone-nourishing bioplasm begins to make bone where we have placed it. It forms osseous tissue on the skin to which we have transplanted it. And each of these bioplasms according to its own functions, whether it forms connective tissue, or nervous tissue, or muscular tissue, carries on its own work definitely, and also transmits to its successor the same faculties which we find it to possess.

Let us return for a moment to the statement about the three substances in the body. We have this *living material* between the other two—the nourishing material and the tissue that is being formed. This living material *must* take up the nutriment before it can be converted into formed tissue. And it becomes in its turn, or rather forms in its turn, tissue that is to be used in the body, giving place to other non-living material that it has somehow impregnated with its own life; thus continuing the process, and making provision for a definite continuance without intermission.

I need not say that when we come to these facts we

are in the presence of unsolved mysteries. We can say nothing whatever concerning the secret of this action. We cannot determine in the slightest degree the inscrutable powers in operation here. And for any one to attempt to teach us, in the presence of these facts, that there is not a something that may fitly be called "life," and which distinguishes organisms from the whole of nature besides, I think is to insult our understanding. But our friends who are acquainted with physiology do not attempt to make any such statements. Professor Huxley, in his celebrated lecture on the "Physical Basis of Life," denying that there is any essential difference between dead and living protoplasm, as I understand the lecture, tells us notwithstanding, that the one *becomes* the other "by subtle influences," or the one *is* the other "under modified conditions." Well, what difference is there between speaking of "subtle influences" and speaking of "life"? or between "modified conditions" and "the living"? We have been accustomed to say "A" and "B" in regard to these facts; he wants us to say "X" and "Y." But that is not moving the matter a single step forward. He knows as we do that there is mystery insoluble. We find that there are "subtle influences," "modified conditions," or more correctly "life," a particular thing that we do not find elsewhere, and that makes the whole organic kingdom separable throughout all time from the inorganic.



III.

PREPARATION OF ALIMENT.

HOMER tells us that when Ulysses had gone to the war, during his prolonged absence and her supposed widowhood, Penelope was entreated by many suitors to enter into a new alliance. Wearied by their importunities, she at last promised that she would think of marriage when she had finished a fabric on which she was then engaged. Faithful to the memory of her beloved husband, she carefully unwound during the night all that she had formed during the day, so that her weaving made no progress during the many years that she waited patiently for her husband's return.

That is precisely what takes place in the human body. We are continually destroying what we have carefully built up. There is a process of destruction and of renewal continually maintained within the frame. In early life, as you are aware, there is a certain very appreciable amount of gain made within the body. It reminds one of a story that is told of a good squire in the country, who, during a time of

prolonged solitude, sought to while away the weary hours by reading the *Vicar of Wakefield*. He was a very slow reader at any time, and his rule was to read *ten* pages each day, carefully placing a mark in the book at the point which he had reached. A roguish niece who was in the house watched him take up the book daily; and as he laid it down she shifted the mark back *eight* pages. When he had finished—for he did make progress at the rate of two pages a day—she asked him how he liked the book. “It is very good indeed,” he said; “but there are a great many repetitions in it!”

During early life we do make progress, but our progress is like the squire’s reading, slow and repetitive. In the process of decay and renewal we make a slight advance, gaining somewhat each time, until we reach what is called the period of maturity. I cannot speak a word, or lift a finger, or move a step, probably I cannot even think a thought, without wasting part of the body; and there must be new material continually supplied to compensate for what is wasted. This new material is furnished in the food that we introduce into the body two or three times a day.

You must not suppose, however, that we can represent the actual arrangement of these materials within the body by any analysis of the food that we supply. For you have listened to these lectures to very little purpose indeed if you have not reached this conclu-

sion—a conclusion, as I think, that is warranted by all the facts—that matter within the body is in a very different condition from that in which it exists without the body. Organised material is certainly not to be compared in all respects to inorganic material. Nevertheless, there is a certain ratio, definite and clear enough, that can be stated, if you please, in chemical terms, between the food that we consume and the amount both of tissue formed and of work done consequent upon the introduction of that food into the body.

I have to speak to-night of the preparation from food materials of this aliment which the organism assimilates and uses. I am not going to enter upon questions either as to the amount of tissue formed or energy expended. Suffice it to say that there is a definite proportion between the food-stuffs and the organic products. My present purpose is simply to talk to you about the nature of the process whereby the food is fitted for taking its part in the structure and service of the body.

Several years ago a very interesting, and in some respects a very instructive, division of food was suggested by an eminent chemist, the late Baron Liebig. He proposed that we should divide all foods into two classes, the nitrogenous and the non-nitrogenous; that is, foods that contained nitrogen as one of the elements in their composition, and foods that did not

contain nitrogen.* He spoke of the one class—the nitrogenous—as tissue-building, and of the other—the non-nitrogenous—as heat-giving. Now if it were possible to verify this division within the sphere of animal life, it would certainly be a very simple and a very valuable one. Unfortunately, however, we find that many so-called tissue-forming foods are used in yielding heat, and many of the so-called heat-giving foods are used in forming tissue. So that this descriptive division is not an accurate one. It is very difficult indeed to find any such distinctions that can be relied on throughout. But I suppose we may fairly (regarding foods only chemically) speak of those that contain nitrogen, and those that do not contain nitrogen, without adding any theory about their tissue-forming or heat-giving properties.

We find that the non-nitrogenous foods are mainly composed of these three elements: carbon, hydrogen, and oxygen. Looking at them more closely, we find that we can divide them still further. There are some in which hydrogen and oxygen are united in the same quantities in which they ordinarily form water. Starch, dextrine, and sugar represent these. There are others in which the hydrogen and oxygen are united in proportions, in which hydrogen is in excess of the quantity required to form water. These are represented by fats and oils.

* Liebig's *Familiar Letters on Chemistry*.

This difference determines somewhat the method of their assimilation within the organism. Let me say here that no chemistry that we are acquainted with can give us full and accurate information concerning what goes on within the body. No processes that we can conduct in the laboratory are in all respects similar to the vital processes that are carried on within the body. And we can gain quite as reliable information—I venture to say much more reliable information—from our observation of the effects produced by different foods, than we can by any analysis of their contents, or inferences founded on that analysis, as to the probable uses to which they may be applied. In other words, our knowledge must really be to a great extent empirical. In fact, we must find out the value of foods by observing the effects that follow the administration of them. We cannot tell beforehand; we cannot prophesy or predict with certainty, from the knowledge that we gain by analysis, what particular purposes, in all respects at least, different foods will serve within the body. But we can tell with considerable accuracy, from a long series of *experiments* and *observation*, the results that are most likely to be reached by the use of different articles of diet.

For the present I make no further reference to these analyses, experiments, or observations. I hope to have an opportunity later on of directing your

attention to some of these questions when I come to speak of food and appetite.¹ My object now is simply to show, so far as I can, what is the process that takes place when the different materials that we take as food are being prepared to take their final place within the body, and to aid in the performance of its functions. Let us endeavour to trace the history of the morsel we put into our mouth from that stage onwards, until we find it ready to assume a definite place in the organism.

On examining the body we find that the reduction of food is accomplished in its passage through a long, irregularly shaped tube, which may be said to begin at the mouth and to end at the lower part of the torso, or trunk. The lining of this tube is an inner skin called mucous membrane, which is continuous with the outer skin, so that, strictly speaking, so long as the food remains in this tube, it has not been received into the body proper, or been applied to its uses.

As I have said, this tube or canal is irregularly shaped—its form and dimensions vary at different stages. In the mouth it begins as a dome-like cavity. Then from the back part of this cavity down to the upper end of the stomach there is a long narrow tube called the *œsophagus*, or meat-pipe. The stomach itself is a larger cavity, of a shape that is almost universally familiar, fairly represented by the wind-bag of the bag-

¹ See *Health Studies*, Lecture I.

pipes. It is to be remembered, however, that, like the bag with which it is compared, the size and shape of the stomach is subject to variation. Sometimes it is very full, and sometimes it is very empty. When empty it is flaccid, and occupies very little room. From the lower or exit end of the stomach we find another tube or canal arising, which, at first of small calibre and disposed in a coil-like fashion, is known as the smaller intestine; but thereafter becoming wider, first ascending then crossing transversely, and afterwards descending to end in the terminal outlet, it is known as the larger intestine.

This intestinal tube is a very long one—thirty feet or more in length. In round numbers it may be said to be *six times* the length of the body. In some animals, vegetable-feeders, like the sheep, this tube is twenty-eight times the length of the body! In carnivorous animals it is very much shorter than in men. The question has been sometimes raised whether the length of our intestinal canal determines our position as vegetarians or flesh-eaters, and it has been deemed satisfactory to affirm that the medium dimension of the canal proves that we are equally fitted to assimilate both kinds of food.

I am not prepared, however, when the question is thus limited, to accept that as a correct answer. If I am not like the one or the other in this particular structure, it does not follow that I am like both. I

may be designed for some other dietary altogether different from that of the one or the other. It might fairly be argued, for instance, that proper food may be neither grass nor flesh, but fruits and farinacea.

The whole tube in which the food is subjected to the process of reduction, whereby it is adapted for nutrition, is sometimes called, appropriately enough, the *alimentary* canal. For some months after birth this tube is very simple, and its various parts are only gradually differentiated. There is at first no proper stomach for the digestion of ordinary food, and the one diet to which infants should be rigidly confined is that which has been prepared for them—the milk of the mother.


Even at the risk of anticipating what I shall have to explain afterwards, I must state at this stage that all the food we take must be liquefied. It must be fitted to flow throughout the body. Not only must it so flow, but it must be so characterized as a liquid that it shall easily pass through animal membranes. Without going into details, allow me to say that liquids of a certain character pass freely through animal membranes, while there are others that cannot so pass. And all the material that we take into the body must not only be liquid, but also in this condition which will enable it to pass freely through the animal membranes—such as the walls of the vessels in which it may be contained—to supply the need of the bioplasts

for the accomplishment of their particular work. In order to secure this peculiar liquidness we have mechanical and chemical processes conducted within the body. I take for granted that you remember that these inner processes are VITAL. We have no such thing as inorganic chemistry within the sphere of organic life. This thing or state which we call "life" modifies all the actions with which we are at present concerned.

When I would use food in any form, the first thing I do, of course, is to take it by the hand, or by an instrument which the hand grasps, and to put it into the mouth in convenient quantity. May I remind you that there are some animals that do not so act? The cow, for instance, introduces the grass to its mouth by its tongue. The horse introduces its food mainly by the lips. In these animals the lips and tongue are what hands are to us. The squirrel, while using its forepaws in feeding, does not take up the nut in the palm of the paw; it balances the nut carefully on the back of its two paws, inclined downwards and inwards, and so secures the kernel.

There are marked differences among animals in the prehension of food. But we may pass these by and suppose that, having divided the food somewhat carefully, so as to take just a sufficient amount to be acted upon, we introduce it into the mouth, to undergo there the first change in the process of digestion.

And may I say here that it is very important, especially if our teeth in these unfortunate times are not so good as they ought to be, that we divide the food carefully before we put it into the mouth. The mouth is a mill, intended for dividing the food, and we find in it several millstones of different shapes. There are millstones for cutting, millstones for tearing, and millstones for grinding. These three kinds of teeth Blumenbach named from their situation, front teeth, corner teeth, and back teeth, and these terms may be accepted as in common use. We have in all, as you know, thirty-two teeth, sixteen in either jaw ; and these are admirably fitted for the work of comminuting the different kinds of food that are suited to the nourishment of the body. When we examine the teeth of animals we find them to be accurately adapted to their necessities ; we discover definite relations between them and the other parts of the alimentary canal ; they accord thoroughly with their purpose and habits. The teeth are fitted for doing preliminary work which ought to be done for the animal's health and well-being ; and by means of the teeth we can form a very good idea, not only as to the kind of food that different animals live on, but also as to their mode of life and general condition. In the human being, as I have said, these teeth are admirably adapted to deal with the different kinds of food that we are in the habit of using. But in civilised life we actually begin



digestion outside the body. We do that by boiling or roasting—by the application of heat in some form or other, for the purpose of making the food more palatable and digestible. It must be confessed, however, that some cooks so change wholesome food that it ceases to be either pleasant or profitable. Do not forget that we have to reduce the food to a liquid condition; any action, therefore, that makes the different parts of the food more easily separable, that breaks it up to any extent, before it is introduced into the body, may aid materially in facilitating this process of digestion. Only let it be remembered, and remembered as a caution, that all the different organs of the body grow stronger and more vigorous by exercise. If we exercise any function within certain limits, that function becomes freer and fuller in its play. So the teeth, the stomach, the glands of the stomach, &c., that are employed in the work of digestion are strengthened by being exercised. And if we digest our food too much before we take it, and reduce it always to pulp so as to give little opportunity for the action of the digestive organs, we may weaken their aptitude, and lessen to a very appreciable extent their available power. If the digestive organs have become inactive or faulty, we may fairly spare them by subjecting the food to some equivalent action before taking it; but in ordinary circumstances they should be expected and allowed to perform their own work. We are able

to some extent to facilitate the process of digestion by culinary skill, and it is needful, often amply, to have recourse to this, in order that we may assist weak digestion. There are conditions of the body in which the digestive process is not carried on very vigorously, and it may be desirable to give food in the most thoroughly digestible condition before it enters even into the cavity of the mouth. Cooking, however, should only prepare the food for natural action, and should interfere as little as possible with such functions as we ourselves are able to perform.

Properly speaking, digestion begins as soon as the food is introduced into the upper end of the alimentary canal; that is to say, as soon as it enters the mouth. It is important that the food should be detained some little time in the lobby. Opportunity will thus be afforded to ascertain its character, and to prepare for its worthy reception. And particularly if the food be in the form of bread-stuff, or other material containing starch, it ought to remain in the mouth a certain time that it may be thoroughly mixed with the *saliva*, which is secreted or prepared by special glands. There are three of these glands: one near the ear, called the *parotid*; another under the jaw, called the *submaxillary*; and another under the tongue, called the *sublingual*. They pour out a quantity of saliva, which is mixed with the food, moistening dry food, and acting specially upon the starchy elements, converting them into a

substance adapted for reception into the tissues of the body. Starch has to be changed into sugar before it can be thus received ;¹ and this change is, at least to some extent, effected by the action of the saliva. On the whole, I am inclined myself, so far as my teeth will allow me, to prefer starch in the form of biscuit, because when we take it in that form we are obliged to keep it in the mouth for some time while it is being ground down, and thus a full opportunity is afforded for what has been termed its *insalivation*. If any of you take a biscuit and chew it deliberately, you will find that it becomes sensibly sweeter, because the starch it contains is undergoing this change. This process of digestion, in which the starchy materials are altered, begins in the mouth. If we swallow food quickly, before we allow it to be thoroughly comminuted or broken up, we burden the stomach with more work than falls to its proper share—in fact, we spare the teeth at the expense of the stomach ; and besides overtasking the stomach, the breaking-up omitted in the mouth may not be fully accomplished later on, and the whole process may be thus marred and made imperfect. We ought to give the food the full benefit of this preliminary detention for these two reasons I have stated—that it may be broken up as far as possible by the action of the teeth, and that the

¹ Strictly speaking, it is changed first into dextrine, then into sugar.

starchy material may be acted upon by the saliva before the food goes further.

Let us suppose, then, that the food has been properly broken up and mixed in the mouth. The mass, or, as it is sometimes called, the *bolus* is moved back into the throat by the action of the tongue, and it is there grasped and passed on by the muscular tissue of the meat-pipe, or œsophagus, into the stomach. Those who are acquainted with the anatomy of the parts know that the breathing-tube lies in front of the meat-pipe. If by any mischance a fragment of food or a drop of water finds its way into the wind-pipe, we suffer considerable annoyance, and immediate spasmodic efforts are made for its expulsion. There is an arrangement of a very neat kind—if you will allow that word—to prevent this miscarriage. I may also add that the breathing-tube has an opening into the nostrils. There is provision made in the upper part of the throat for closing that entrance to the nostrils, and there is provision made at the same time for closing the entrance into the wind-pipe while the food is being carried into its own proper receptacle. Let the space between the forefinger and thumb represent the entrance to the wind-pipe, while the tube down which the food is to pass lies behind the forefinger; the food in its passage backwards closes the valve which protects the opening of the wind-pipe, just as we close the opening between the thumb and fore-

finger by pushing the thumb back upon the forefinger.

When food is introduced into the meat-pipe it does not fall down simply according to the law of gravity. If material be thrown into an upright iron tube, open from the top to the bottom, of course it would fall down by the action of this law. But this meat-tube, as I have said, grasps and pushes the food downward. We find a circular band of muscular fibres along the whole length of the tube, and these so act, when stimulated by the presence of the food, as to squeeze it onward and downward. It is pressed down in this way as if I were gradually to squeeze onward a mass enclosed in an indiarubber tube. This kind of action, which we find also in the intestines at the other end of the alimentary canal, on account of its worm-like progression, is often spoken of as vermicular. You can observe this process if you look at a horse in the act of drinking. You notice that the horse's mouth is down much lower than the upper part of the throat, and the water that is drank must be carried up against the law of gravitation. If you look carefully you will see something like a ball pass along the throat as each gulp is taken. The constricting muscles are forcing each mouthful of water upward and onward into the stomach. Jugglers, because of this arrangement, are able to astonish the ignorant by drinking a glass of water while standing on their head.

When the food has reached the stomach, what action takes place there? We have learned already that digestion *begins in the mouth*, and I wish you now to note that it *does not end in the stomach*. Although a very special process is conducted there, the food is not prepared to enter into the circulation even when that process has been completed. Nay, after it has left the alimentary canal, it is not prepared even then to enter into the circulation. Part of it passes through the liver, and all of it has to pass through the lungs, where it receives oxygen from the inbreathed air; but to this latter action I do not ask your attention now, because it will come more naturally before us when we study the *circulation* of aliment.

What takes place, then, in the stomach? As I have explained already, the stomach is shaped, when it is fairly distended, something like the wind-bag of the bagpipes. At the upper end, lying to the left side of the body, we find the entrance to the stomach, where the food received from the mouth enters through the meat-pipe; at the lower end, lying to the right, a little beyond the middle line of the body, we have the outlet where the food, after due preparation, passes into the duodenum,¹ the next part of the alimentary canal.

The food in the stomach has to be "dissolved" (I do not know a better word) to some extent. If I

¹ This term is derived from a Latin word meaning twelve, because it is about twelve fingers' breadth in length.

were to put a lump of sugar in a glass of water, and leave it for some time, the lump would disappear though the sugar would remain, and I would say that the sugar had been dissolved in the water. If I were to put a piece of beef or mutton into the glass of water and leave it for hours or days, it would not dissolve or disappear, because the water has not the power of so acting on meat. Now the bread and meat that we take have to be dissolved; they have to be liquefied so that they may be carried throughout the whole organism. And this liquefaction¹ has to be accomplished during the process of digestion, and a very important approach to it is undoubtedly made within the stomach. We have three different tissues in the structure of the stomach. There is the outer part (serous membrane or tissue), to which we need not pay much attention now, which allows it freedom and ease of motion. We have next to that the muscular tissue, to which I will call your attention presently, and within, the mucous coat or tissue lining the whole cavity. You will understand what mucous tissue is when I tell you that the inner skin of the lips is mucous tissue or membrane. In this mucous tissue we have a great many little glands—great masses (when I say great I am speaking of their number rather than their size, for they are really

¹ Of course there are other changes effected on the food besides making it thus transportable.

microscopic), great bundles of little vessels crowded together for the performance of certain work. These glands^{*} get their material from the blood, and form or secrete a peculiar fluid called stomach-juice. It is called *gastric juice* in scientific treatises; but that title is derived from a Greek word (*gaster*) meaning "stomach," so that really it is only stomach-juice after all. We can analyse it and discover what it contains.

At this stage it may very properly be asked, how is it that we know anything of what takes place within the stomach? It so happens that we have gained a great deal of information in regard to the stomach's action from observations and experiments made in the case of a young Canadian who was, I think in 1822, the subject of an accident which left a very convenient opening into that important organ, the stomach. A gun was discharged within a yard or so of his body, and some of the shots were lodged for a time in his abdomen. Part of the abdominal wall in front was carried away and an opening made into the stomach. He did not die, but recovered under careful treatment, and I believe is living still—at least he was a year or two ago. He was under the care of Dr. Beaumont, a most intelligent and painstaking observer, who con-

^{*} "Glans" is the Latin word for acorn; and these *little masses* of vessels are called glands because of a fanciful resemblance to acorns.

ducted for seven months a series of well-arranged and valuable experiments for the purpose of ascertaining the nature and characteristics of stomachal digestion. A full account of his observations and experiments has been published in an interesting volume.¹ A great many other experiments have been made on animals by vivisection. But these are subject to the objection that we cannot predicate that precisely the same processes take place in human beings; and further, where you cause such disturbance of the nervous system by the infliction of pain you produce other results that may vitiate your experiments. I do not wish to go out of my way to say anything in regard to vivisection, but it is a rather suggestive fact that the information gained by vivisection is frequently conflicting and sometimes contradictory.

In the case, however, that I have mentioned we have a great amount of information conveyed to us in regard to the operations of the stomach and of the gastric juice that is thoroughly reliable. Both the facts that have been observed and the conclusions that have been based on these experiments are generally accepted by physiologists. You will find a very interesting and readable account of Dr. Beaumont's investigations in Dr. Andrew Combe's *Physiology of Digestion*, a most valuable book, though written a good

¹ Beaumont's *Experiments and Observations on the Gastric Juice*. Boston : 1834.

many years ago.¹ I remember reading it, I do not choose to say how many years ago, and I have at this moment a distinct remembrance of the pleasure I derived from its perusal. Well, we learn from these observations and experiments made by Dr. Beaumont what takes place within the stomach. We know that the food when it enters that organ is made to traverse the whole cavity from left to right, returning again from right to left. It takes a little time to make this circuit, and by means of the muscular tissue which we found in its structure this action is maintained regularly during the process of digestion, so that the food is continually being sent round from one end to the other. While it is making this circuit the gastric glands are pouring out great quantities of stomach-juice, which is thus brought into contact with the different parts of the surface that are successively exposed. As the food travels round the stomach and is thus acted on it is partially dissolved, and this pulp, or as it is called in books, *chyme*, is carried on to the exit end of the stomach, where it is allowed to pass out if found to be sufficiently prepared. By this action of the gastric juice on the external part of the mass we have successive new surfaces exposed and pulped until the whole mass

¹ *The Physiology of Digestion Considered with Relation to the Principles of Dietetics.* By Andrew Combe, M.D. Recent editions bring the information up to date.

has been reduced to the right condition. We cannot by any mechanical means stir the food in the stomach ; but this organ, by means of its muscular fibres which send its contents rotating from one end to the other, contrives most effectually both to stir round these contents and to mix them intimately with the fluid which it secretes. That fluid, the stomach-juice, has the power of dissolving or acting upon, to a certain extent at least, certain materials it finds in the food. There are some materials on which it exercises no power. It does not change the starchy parts or the fatty parts, but the muscular parts, such as the lean of meat, it softens and separates. It dissolves the connective tissue, which, you remember, is the part that binds all together, and in that way the muscular fibres are easily separated and disintegrated prior to their entering into the blood. Indeed, the stomach, by an organic process which is nevertheless both mechanical and chemical, prepares the food for becoming blood. It does what might to some extent be done by heat ; but it does this at a comparatively low temperature. The temperature of the stomach is somewhere about 100° , and of course we cannot boil meat except at a temperature of 212° . So that, although a similar result is reached, we are not entitled to say that the process of digestion is a physical one. In this way it acts on the fibrous parts of the food, breaking them up and preparing them for

entering in solution into the blood. The stomach-juice acts chemically on what are called albuminous substances. These substances are of the same character and composition as the white of egg, which may be regarded as typical albumen. This white of egg and its allies are not readily soluble in water, do not pass through animal membranes, and are coagulated by heat. After submission to the action of this fluid in the stomach, the character of these albuminous substances in these respects is reversed; and they are thus thoroughly adapted for assimilation and serviceableness in the body. In this new and *digested* condition they are called *peptones*. The organic principle in gastric juice which acts after this fashion is called "*pepsine*."¹

In order that the stomach may do its work effectively there must be a sufficient supply of gastric juice forthcoming to act upon the materials that have to be altered. I have no doubt that some will think that I am exaggerating when I say that the amount of gastric juice that is formed in the stomach in the course of a day has been estimated, with considerable accuracy, at fourteen pounds. Indeed, we form also about two pounds of saliva daily within the mouth; and I was somewhat amused the other day, when thinking over this subject, to find, as my attention was called to it, that I became subject to a rather excessive mouth-watering. Probably my attention

¹ Pepsine, from the Greek word *pepto*, which means to cook.

being directed to these salivary glands had excited them to rather more vigorous action than usual. Yet this large amount of saliva, and this much larger amount of gastric juice secreted in the body, are not in any sense wasted ; the whole quantity of both enters into combination with the food and is received into the organism, and is afterwards, in its elements at least, available for the very same purposes that it has been employed to subserve already. It flows in a shut circuit, and these two pounds of saliva and fourteen pounds of gastric juice,—like a score of supernumeraries on the stage, who may be so repeated by a skilful manager as to represent an army several hundreds strong,—might presumably, if there were no waste, do duty over and over again.

Still there must be for the digestion of the food within the stomach healthy action on the part of these gastric glands. Dr. Beaumont observed the circumstances in which they were excited, and he tells us that the introduction of any substance into the stomach awakens their activity. When they are busy at work, a great many glistening drops form and gradually flow down the inner lining membrane of the stomach in little rills. When the action was vigorous and healthy, the fluid thus formed could act effectively on suitable substances. But many causes may arrest the action or alter the secretion of these glands ; for instance, fear, anger, anxiety, and other mental affections seem

to exercise a very marked influence on the whole process.

I ask your attention to this fact, because nowadays we are frequently reminded that the body acts on the mind, and it is well to remember sometimes that the mind acts also upon the body. And we find that when the mind is excited or harassed this stomach-juice is either lessened in amount or altered in character, so that it is found insufficient for the digestion of the food. This weakness of function is indicated by loss of appetite and relish for food. Nevertheless, it is notorious that when the desire for food is wanting, some officious friends are sure to insist on the necessity of food consumption. They are anxious to pour food into the stomach at all hazards. But the stomach is a better guide in these cases than any officious friend can possibly be, and where it refuses to welcome food that refusal may be taken as a sure indication that it is useless and vain to place food within it. When people are weak from illness, their friends are often anxious that they should eat a great deal. And I am willing to admit that they would recover more quickly if they could assimilate easily large quantities of nutritious food. But when they are not able, even thus far, *to digest it*, excess of food forced into the stomach only acts as an irritant, and gives rise to more distress and weakness than they would otherwise have to endure. I

believe, if we paid more attention to what we may fairly call the voice of nature, we should be healthier and stronger than we are. We can only digest a certain amount, and the amount we can digest is the amount that is available practically for the body's use. Any excess of any kind is wasted, and, moreover, it hinders and mars the digestive functions of the stomach. In cases where the stomach is so weak that it cannot digest, it is very important to give the food in such a condition as to require almost no stomachal digestion. It has been found practically in some cases, such as the weakness of typhus fever, that the best food we can give is childhood's food—milk. Professor Gairdner, of Glasgow, proved this brilliantly by treating thus a large number of fever patients in the Royal Infirmary of that city, the number of recoveries secured being largely in advance of those attainable by other treatment. Previously it was customary to give wine freely to fever patients who seemed in danger of sinking from loss of strength. The milk treatment beat the old wine treatment out and out, and there has been a marked change in practice ever since.

All food must be properly prepared in the stomach before it is allowed to pass the outlet, called the *pylorus*, from a Greek word meaning "gate-keeper." There are certain muscular fibres that constrict, in a valve-like manner, this outlet, and these fibres only expand or relax to allow the food to pass out of the

stomach when it has been properly digested there. When the food has undergone this appropriate change, it is called chyme, and when the chyme comes to this "gate-keeper" in a pulpy or sufficiently reduced state, it at once allows it to pass; but "rude undigested masses" are turned ignominiously back. By-and-by, when they have come a great many times, and the "gate-keeper" finds that the stomach can make nothing of them, it allows them to go, so to speak, under protest, in the hope that something may be done with them elsewhere. There are some matters that cannot be digested anywhere, such as the woody fibre in certain vegetables. These pass on through the whole length of the intestinal tube, and are thrown out unchanged.

Food remains in the stomach ordinarily between two and four hours.¹ I do not think we should put fresh food into the stomach until the former meal, if it has been a fair one—or, as our American friends would say, a "square" one—has had time to get on far enough to leave that organ free to begin work again without any drawbacks or arrears.

When the chyme has passed into the first portion of the intestine, called, as you remember, the duodenum, it is mixed there with other two fluids—one supplied by the liver, and the other by the pancreas,

¹ The time varies according to the "solubility" or "digestibility" of the substances composing the meal.

or sweetbread. The liver is not merely a secreting organ ; it is, to a large extent, an excreting organ also, withdrawing from the blood certain materials of which it is necessary to get rid. To that filtering function we give no attention at present. Let us note, however, that it forms a special product called "bile," which is of a reddish-yellow colour, and is the principal agent in the digestion of fats. It enters into combination with the fatty constituents of the food, sometimes forming emulsions, and sometimes forming soap-like substances. There are in the liver a great many bile-making glands congregated together in masses. Lying on the liver, and having open communication with it by a duct, there is a reservoir called the gall-bladder, in which a certain quantity of bile is stored up ready for use. Part of the bile is apparently intended to be thrown out as waste ; it passes away with the undigested parts of the food, and indeed assists indirectly in their removal. I ought to say further that the bile seems to act in a somewhat strange way by arresting and altering the digestion of the peptones.* I am inclined to ask whether the bile may not be thus used in correcting any excess of action that may have taken place within the stomach, neutralising any over-result of gastric digestion. However, that is a question for

* Nitrogenous substances that have been prepared for absorption by the action of the gastric juice are called "peptones."

further inquiry. The great use of the bile, so far as we know at present, is partly to emulsify the fats, and to make them soap-like that they may be in a proper state for ultimate assimilation.

The pancreatic juice is similar to the saliva, and acts upon the materials that are subjected to it after the same fashion. It changes the starch that may be found in the duodenum, and which has not been sufficiently acted upon in the mouth, into a soluble sugar, so that it may pass easily through animal membranes to its place of service in the body. We find also that there is thrown out from the intestine itself a certain amount of what is called intestinal juice, which seems to be in quality a weaker kind of the other juices that we have found already supplied ; so that if any particle has escaped solution, the intestinal juice may take up and complete the task.

The food is detained a considerable time in the smaller intestines. These form a long, continuous tube (about twenty-five feet in length), and are arranged in a coil-like manner in the lower part of the abdomen, evidently for economy of space. They furnish accommodation for a very large amount of material. Besides, they have certain expansions called *valvulae conniventes* (helping-folds), that increase their superficial area very much, so that they allow a very wide spread-out of their contents.

From this extensive area the materials that have

been formed through digestion in the mouth, stomach, and intestines are sucked up by little leech-like vessels called lacteals, and carried into the thoracic duct, from which they are transferred to one of the veins, and emptied into the heart. From the heart they are sent into the lungs, where, being mixed with air, their transformation into blood is complete.

I ought to say, in regard to these helping-folds (*valvulae conniventes*), that they are of great use in enlarging the area of the intestines. By these windings and turnings a very large amount of surface is contained within a narrow compass.

There is a story told about an Englishman and a Scotchman, who were disputing about the relative excellences of their respective countries. The Englishman maintained that his country was superior to Scotland, and, of course, my countryman maintained the opposite. They argued the question, *pro* and *con*, at considerable length. At last the Englishman said, "You must admit that in one respect England is superior to Scotland—it is larger." "I do not know that," replied the other; "because, you see, in Scotland we have a great many high hills, and if they were beaten out flat, like the plains of England, you would find that perhaps Scotland was much the larger after all." Well, these helping-folds are like the mountains, because of the larger surface which they expose; they detain the chyle a longer time, and allow all the nutri-

tive material to be extracted by these little lacteals, so that we have all the gold extracted from the ore and transmitted to the minting chamber, where it is duly stamped and passed into the currency.

IV.

CONVEYANCE OF ALIMENT.

MILITARY strategists have learned the importance of supplying their armies with food. It is not sufficient that they have some communication with the place where food may be obtained ; they must secure its conveyance freely and amply to the combatants. They know that if they can surround a city or camp so as to cut off the supply of nutriment, surrender is only a question of time. And they know as well that if they are removed from their own base of supplies, so that they cannot feed their combatants sufficiently, these combatants will not long continue in a fit frame for fighting.

It is not enough that we have production ; we must have conveyance of material. I hear it sometimes said that wealth depends entirely on the produce of the soil, and the producer is credited as the creator of wealth. It seems to me that in society as at present constituted wealth depends as really upon those who are engaged in the interchange of material as upon those who are engaged in its production. Commerce

is advantageous to the body politic no less than agriculture, and our lives would be very limited and very poor were it not for the wide ramifications in which the exchange of commodities enriches the peoples of the world.

I do not dilate on this, although it is a tempting subject. My present purpose is simply to speak to you concerning the conveyance of aliment within that wondrous though narrow organism, the human body. Will you be surprised to learn that water is the medium by means of which this conveyance is secured? If I were to cut off the river Thames below London Bridge, so that no vessels could come up to the city; if I were also to destroy the railway lines round about London, so that no trains could run in; and if I were likewise to block up the roads, so that no waggons could reach our streets, we would be starved within a few weeks. It is not enough that there be plenty in the world, or in the empire; the plenty must be brought to our towns and to our homes that it may be made available for us as individuals.

Now what these various modes of conveyance are to cities, that, and more, water is to the human body. It floats all the solid nourishment of the frame to the various parts of it where that nourishment is required. When I examine the body I find that water forms by far the largest amount of its bulk and of its weight. A body weighing 165lbs. will contain about 110lbs. of

water ; so that water forms about two-thirds of the whole. If we were entirely to dry the body—to drive off all the water it contains—it would become very light indeed.¹ The most solid structures of the body have water in them, otherwise they would cease to live. We have water in the bones, no less than in the flesh.² We find water abounding everywhere throughout the body. And although it may have other uses—on which it is not my purpose to dilate—its main use is to serve in conveying all the different materials that are needed to each individual tissue and territory of the human frame. Nothing can serve this purpose except water. You may get it in various combinations — pleasantly flavoured in fruits, and sometimes very unpleasantly flavoured in rivers, and sometimes very injuriously associated with alcohol. But it is the *water* that is serviceable wherever we find it ; and water is good, no matter though it be in bad company. It is the water that people imbibe in drinking beer that alone serves this useful purpose in their frames. It is sometimes said that total abstainers are great water drinkers ; but I venture to say that they drink less water than those who use strong drink. The users of spirituous liquids must consume a considerable proportion of water. There is no man alive

¹ Blumenbach had a mummy which weighed only 7½lbs.

² In bone, water forms about 22 per cent. ; in muscle and brain, about 75 per cent. ; in connective tissue, about 79 per cent. ; and in the vitreous humour of the eye, about 97 per cent.

bold enough or foolish enough to consume pure, absolute alcohol. Water to dilute and sheathe it must be taken along with this poisonous substance; and in most instances the water very largely preponderates. Besides, the use of alcohol engenders a thirst that calls for larger and still larger supplies of the "limpid element;" whereas those who are in the habit of keeping their blood cool² and free from such ingredients are not tormented by this raging desire for fluids. I do not think that I drink much more than a gallon of water in the year, *as water*. Of course I take tea; sometimes, though very rarely, coffee; and very frequently milk, which I regard as one of the best forms of liquid food that we can take. And when we take water in tea, coffee, soups, &c., the water has been, or ought to have been, boiled, and any organic impurities that it may contain are thus likely to be destroyed. Pure cold water seldom passes my lips, not because I despise it, but because I feel no desire for it. I am very fond of fruits. They suit my palate; and I find in them a very large quantity of water very pleasantly flavoured by a natural process. And let me say here that those things that are pleasant

² "I am strong and lusty;
For in my youth I never did apply
Hot and rebellious liquors in my blood;
Therefore my age is as a lusty winter,
Frosty, but kindly."

As You Like It, Act ii. Sc. ii.

to us are *generally* good for us. We were taught somewhat differently when we were boys and girls, perhaps to save the contents of the sugar-basin. We were solemnly informed of dangers to teeth and stomach in the consumption of sweets. But negroes in the cane-fields who eat large quantities of sugar do not spoil their teeth or stomachs in doing so. The things that are sweet and pleasant to the unsophisticated palate, and that our natural appetite desires, instead of being bad for us are commonly good for us. You may take that as a safe general rule. Animals follow it, and we are animals in our material structure, and we do well to follow our instincts in this direction even as they do. Of course we are *reasoning* animals, and I must add that these instincts are consequently to be followed within *rational* limits.

Water, then, plays this important part in the organism. It is the *medium of conveyance* by which the different materials are brought to the several places where they are required. Water enters largely into the composition of our food; and there are very few kinds of food—I am not sure that I can name one—in which we do not find a notable amount of water. We call bread “dry,” but it contains a very noteworthy amount of water. If we take a slice of bread and, putting it on a toasting fork, hold it before the fire, we find that steam escapes from its surface; that is, as we know, the water it contains is evaporated

by the heat. We find water in the fibre of cotton wool. We do not, of course, use that as a nutriment, but I mention it as an illustration of the fact that water is to be found in certain places where we would not expect to discover it. I may say, I think safely, that all the food we are in the habit of using contains more or less of this element—water. It has even been said by some—though I am not prepared to accept their doctrine—that we ought never to drink water in its free condition; that we ought to take it in its natural combinations, in fruits, farinacea, &c.; and that in this way the wants of our bodies can be freely and best supplied.

However, as we have found that water enters into the composition of our food, so we find it in those substances within the body that act on the food. We find it giving flow and penetration to the saliva; we find it likewise bringing the active principle of the gastric juice to bear upon the contents of the stomach; we find it in the bile, and in all the juices and secretions of the body.

In a former lecture we followed the food from its entrance into the mouth to its reception into the thoracic duct—a vessel not thicker than a common goose-quill, which runs up in front of the backbone, beginning near the upper part of the intestines and running up to the region of the heart. This canal empties its contents—called “chyle,” and received

from the lacteals, or little leech-like vessels, that dip into the intestines and suck up their contents—into the superior *vena cava*, or hollow vein, which conveys them into the right *auricle*, or right receptacle of the heart. At the same time that the chyle comes into this superior vein it is mingled with a very large amount of fluid matter that is poured also into the same receptacle.

I have not yet spoken of another series of vessels that we find in the human body, called “lymphatics”—vessels that take up waste materials and carry them by a circulation of their own from all parts of the body, emptying them at last into this same superior hollow vein, by which they too are conveyed to the upper right side of the heart. Now we have to learn here that the blood that is being formed, the fresh chylous material that has been produced by the digestion of the food, and the waste material—shall we call it “the sewage of the body”?—are mixed together and carried, in one current, into this right receptacle of the heart. I do not think we have anything like that in our cosmical engineering. We have these elements mixed intimately together, preparatory to the process of conveyance of aliment throughout the system—the waste material and the new material that is to take part subsequently in the process of living.

The heart, as you are aware, is a double organ. It is divided in the centre by what is called the septum,

or division, into two sides, a right side and a left side. And each of these sides is divided into two chambers, an upper and a lower. That is not so in all animals. There are some animals that have no heart at all. I do not mean that metaphorically, but literally. And there are others that have only one heart—not a double heart, as we have. Again, I do not mean to use these terms metaphorically, but literally. Fishes, for instance, have only a single heart, and consequently a single circulation. But in man we find a double heart and a double circulation. We have the sides—the right and the left—and we have corresponding to these two sides two circulations—a circulation through the lungs and a circulation through the whole body. One is called the pulmonary or lung circulation, and the other is called the systemic circulation, or circulation throughout the whole system.¹ Any one could tell readily enough, having that information, which side of the heart is the stronger. Of course, the one that has the larger amount of work to do. The right side is the side employed in what I have called the lesser circulation; the left side is the side employed in the larger circulation. I have said that there are two chambers—an upper and a lower—in each side of the heart.

¹ Perhaps it may help the memory to think of the heart as a two-floored house, with two reception-rooms in the upper floor and two work-rooms in the lower.

These two chambers are called respectively, in both divisions, the auricle, or receiver, and the ventricle, or discharger. One takes in and the other gives out. I am dwelling on this, speaking somewhat slowly, because I am anxious that you should apprehend readily, as I think you may by even a very slight attention to this matter, the nature of the construction of the organ which is the fountain of the whole circulatory system. May I repeat in a sentence, so that there may be no mistake, that the heart is double: one side—the right—being employed in the circulation through the lungs; the other side—the left—being employed in the circulation through the whole body. On both sides there is a receiver and a discharger, an inlet and an outlet. I prefer calling the one a receiver and the other a discharger, because, in the latter case particularly, the word suggests the employment of force in sending forth the blood on its different journeys.

Well, we find this *vena cava*, as it is called, emptying its contents into the upper right side of the heart. These contents are, at the same time, as soon as received, passed from the upper into the lower chamber. Then the contents are forcibly expelled by this right ventricle or discharging chamber into the *pulmonary artery*, the canal in which they are carried to the lungs. I ask your attention for a moment to the name given to these vessels, one of which goes to each lung. Ordinarily we speak of the arteries as containing one kind

of blood, and of the veins as containing another kind. We find two kinds of blood in the body—a bright red or vermillion-coloured blood, commonly called arterial ; and a dark, purplish, almost black blood, called venous blood. These two kinds of blood are so called because they are found in the arteries and veins respectively. *In the pulmonary arteries we find dark venous blood*, the very opposite of that which we find in other arteries. In this instance an artery carries venous blood. But then, please to note, it carries blood *from* the heart, and *that* is the distinctive characteristic of arteries. Arteries, in *anatomical* language, are those vessels that carry blood *from* the heart, no matter what may be the colour or character of the blood they contain. Veins are those vessels that carry blood *to* the heart, no matter what may be the colour or character of the blood.

Within this artery carrying the dark blood there is the chyle ; the waste material brought back by the lymphatics ; and the return blood supply received from the veins. It has been said truly that in this one current flowing from the right side of the heart into the lungs you find the blood of the past, of the present, and of the future.

Please to observe, that we are not yet done with the preparation of the aliment, though now we are following its circulation. In the very beginning of its progress we find the blood undergoing a further

change. This may be considered an intermediate stage—partly preparation, partly conveyance.

The lungs, into which the blood is carried, are peculiarly constructed. We have descending from the back part of the throat, and in communication with the nostrils, the trachea, or windpipe, which, branching off to the right and to the left, divides into two tubes called the bronchi, or bronchial tubes, one of which enters each lung. These tubes, on entering the lung, give off a great many distinct branches. These again ramify into an innumerable multitude of twigs that occupy the whole extent of the lungs. Then, on the other hand, the pulmonary artery, of which I have spoken, when it reaches the lung gives off a similar number of branches, and these are divided and subdivided after the same fashion; these minute vessels, reassembling and enlarging in reverse order to form what is called the pulmonary vein, in which the changed and purified blood is to be returned to the heart, and this circuit of vessels occupies also the extent of the lung. If it were possible to dissect out the air communication—the bronchial tube, with all its branches—we should have a bush-like mass representing the size and shape of the lung; and if it were possible, on the other hand, to dissect out the pulmonary vessels, with all their branches, we should have a similar bush-like mass. And these two, the air-tubes and the blood-vessels, are throughout

conterminous. The air-tubes end in lobules or little berry-like cavities, in which the capillaries or hair-like vessels come in contact with the enclosed air. The lung itself may be compared to a big sponge. Suppose we take a piece of the lung-tissue distended with air and put it into water—it floats, because, with the contained air, it is lighter than water. This is one of the methods that medical men use for ascertaining, in cases of supposed infanticide, whether the child has breathed after its birth or whether it has been still-born.²

These vessels from the heart, getting into all parts of the sponge—allow me to use that term as a helpful one—convey the mass of blood into it that they have brought from the right ventricle of the heart. And there the blood meets with the air brought in through the nostrils. You notice I say the nostrils, but I do not mean to say that is the right word in all cases. Because, unfortunately, a great many people breathe through the mouth rather than through the nostrils. But the nostrils, and not the mouth, are intended for breathing. And one reason I have for calling your attention to this fact is that, if we breathe through the mouth, the air is not properly warmed before it comes into contact with the delicate tissue lining the bronchial tubes. I think oftentimes colds and coughs are caught by an unguarded opening of the mouth, especially on

² Taylor's *Medical Jurisprudence*, p. 434, 7th edition.

going out of heated rooms into the cold winter atmosphere. I make it an invariable rule to keep my mouth shut after going out of a heated room, and by doing so I have had a wonderful facility in escaping colds and coughs. Always when possible we should breathe through the nostrils. We should acquire this habit so thoroughly that during sleep breathing shall go on easily and unconsciously with the mouth closed. The nostrils are intended for breathing. The air is warmed in the chambers of the nostrils sufficiently before it reaches the delicate membranes, and it is not deprived in any degree of its valuable qualities. It enters the wind-pipe and bronchial tubes as pure, but not quite so cold.

Well, the air coming into the lung is carried by the tubes into the lobules, or berry-like cavities, where it meets with the blood. But you may tell me the blood is contained in vessels, and the air is contained in these cavities, and there is no opening between them ; how do the two come in contact with each other ? It is not true, as some have thought, that blood, poured out anyhow, nourishes the body. Nor is it true that air brought in anyhow, is fitted to accomplish its work in the body. If blood is thrown out from the vessels (extravasated) under the skin, it does not nourish ; it must in that case be removed. Instead of being a nutrient material it is a waste material that the body must get rid of. It can only

nourish when it is contained in shut vessels. And from these shut vessels the particular elements in it that are requisite are going out after a special fashion of their own. I am going to use two big words, but I hope you will understand their meaning before I am done with them. They are *endosmosis* and *exosmosis*. They are quite as easily understood as protoplasm or bioplasm. Suppose I take a bladder, which is an animal membrane, containing, say, a solution of salt, and dip it into another vessel containing a like solution of salt, there is no interchange between the two solutions. But if I take this bladder, or animal membrane, containing the solution of salt, and put it into a vessel containing water, I find that the water in the vessel becomes saline, and that the solution in the bladder becomes weaker. Some of the elements in the bladder pass out into the vessel, and some of the elements in the vessel pass into the bladder. There is a going out and a coming in — *exosmosis*, going out, or pushing out, to give the correct rendering; and *endosmosis*, a pushing in. Where we have liquids of different densities, we find that there is this interchange of their contents through animal membranes. The blood being different in density from the other fluids with which it comes in contact, the animal membrane or capillary in which the blood is contained allows some of its contents to pass freely through; and, on the other hand, some of the fluids

with which it is surrounded pass freely in. There is a going out, or pushing out, and a pushing in.

Now let me tell you what is done in the capillaries. Harvey, as you are aware, discovered the circulation of the blood. There can be no doubt whatever of that. A great deal was known and accepted on this subject before his time; but to him belongs the honour of having made it perfectly clear, and of having established it in such a way that it has been, to a very great extent, the beginning of true physiology. Michael Servetus undoubtedly knew a great deal and suggested more. You will find it stated in some books on this subject that Calvin roasted Servetus and his books, and in that way delayed the discovery of the circulation of the blood. Now, believe me, Calvin did nothing of the kind. He held certain doctrines which Servetus denied, and it was the custom in those days for the parties that could control the secular power to burn heretics. We have got rid of all that wicked nonsense. But all parties alike held that miserable doctrine in Calvin's time, and probably Servetus would have consented to Calvin's death as readily as Calvin consented to his. They were all equally mistaken on this particular subject, and I do not vindicate one side or the other. But to say that Calvin exhibited any special malice or malignity, as is implied in the accusation that he "roasted Servetus," is certainly to make an assertion which the facts of history do not warrant.

Harvey, however, did not demonstrate this circulation in the capillaries ; he seems rather to have thought that the blood flowed chiefly through pores from the small arteries into the small veins.¹ In that case, would there not be an irrigation of the body by blood similar to the irrigation of earth by water? Four years after Harvey's death, Malpighi demonstrated by the microscope what we know as capillary circulation. We know now that the blood circulates in shut vessels from first to last. It comes from the heart contained in vessels, and it goes back to the heart contained in vessels. There is no breach of the continuity, no "solution" of the continuity, as our surgical friends would say, throughout. It is within shut vessels from its going out to its return.

Now, in these little vessels in the lung the blood is brought into contact with the air that we inspire. For we have to learn further, that as there may be an interchange of liquids of different densities through an animal membrane, so there may be *interchange of gases* ; and it is this interchange of gases that takes place in the lungs. You remember that the blood as it flows into the lungs contains both the new supply sent from the stomach and the old supply transmitted by the veins. In that old supply there are waste substances that have been taken up in the circulation, and among these there is a certain amount of *carbonic*

¹ Da Costa's *Harvey and his Discovery*, p. 51.

acid gas. We take in, as we breathe, a large amount of atmospheric air. We do not give out in return the whole gaseous contents of the lung ; that is to say, we do not empty the lung, nor do we inflate the lung completely at each inspiration. There is always a reserve stock, so to speak, in the lung. We take in, as I have said, a large amount of atmospheric air. You know that air is composed of two gases, nitrogen and oxygen. So far as we know at present, nitrogen seems mainly to be used as a diluent ; that is, to limit the amount of oxygen, and consequently to lessen the action there would be if it were breathed alone.

Oxygen is the one element in atmospheric air that, so far as we know, is employed within the body in doing work. We take in this oxygen into the lungs, where it comes into contact with all these small capillaries in which the blood is contained. The carbonic acid gas contained in these capillaries passes out through the membrane, and the oxygen inspired passes in. The carbonic acid gas escapes into the air cavities, and the oxygen makes its way into the blood-vessels. The oxygen thus gets into the blood, and is carried from the lung to the heart, thence to be sent on its travels throughout the whole body ; while the carbonic acid gas, which is thrown out in the lung, passes out into the atmosphere by the return breath, or expiration.

We get rid, in this way, not merely of the carbonic

acid gas, but of other things as well. For, let me remind you of what I said in the last course of lectures, that there are other materials passing off in the breath.

We give off water, which you find deposited on the walls of rooms within which a great many people are breathing, or which you may find collecting on the sides of a glass into which you breathe for a few moments. We also give off certain waste animal matters. And these substances are substances of which we ought to be rid. Now is it not common sense that if these various materials, carbonic acid gas, &c., ought not to continue in my body, they ought not to be received into yours? And if I breathe them out, you should not breathe them in. If they are bad for me, they are not good for you, therefore you should not inhale them. That is the whole secret on one side of the value of ventilation. We must have these foul products removed; and, on the other side, we must have the element of oxygen freely supplied.

We have thus endeavoured to learn how the carbonic acid gas is removed from the body, and how oxygen is introduced. In consequence of this exchange of old for new—waste material for vitalising oxygen—we notice that the blood, which as it came from the right side of the heart into the lung was dark or purplish black, goes back to the left side in a bright vermillion-coloured stream. And this change in colour is mainly due, so far as we can ascertain, to this intro-

duction of oxygen and dismissal of carbonic acid gas.

It is a very interesting question, in what form does this oxygen exist in the blood, and how is it carried along in the current? So far as can be determined, we find that it is carried by means of little discs, commonly called the *red corpuscles* (little bodies) of the blood. These are very small; we cannot see them with the naked eye. They may be described as something like half-sovereigns in shape; in a drop of blood under the microscope, we may see little masses of them lying together like rouleaux of coin. They are so small that it would take 3,000 touching at their edges to form an inch in length, and 12,000 placed one above the other to form an inch in height. Yet it is by them, apparently, that the oxygen is transmitted in the circulation, and they are, on this account, sometimes called oxygen-carriers.

Perhaps you are not prepared for this fact, that this oxygen, which is so often called the life-giving element, is mainly used in the destruction of the body. Yet without it we cannot live for five minutes! I can live without food—well, perhaps two weeks, or even more. That depends entirely on the fatness of the individual and other circumstances. There is a story told about a fat pig having been imprisoned for a long time by the fall of a chalk cliff under which it had been feeding. At the end of its long-continued

enforced abstinence, when rescued, it was as thin as a whipping-post. It had been living on its own fat to the great loss of its owner. It had literally been devouring itself; thus lessening considerably its commercial value. Different people can live a longer or a shorter time without food, according to circumstances. But we may live, at all events, for several days without food. I suppose we could live without water for three, perhaps, or even four, days; but we cannot live without oxygen for more than three or four minutes! If you put a man's head under water for five minutes, he will never lift it again himself; that will have to be done for him. Five minutes of this immersion would be quite sufficient to kill the strongest of us. I believe that there are some cases in which people have been immersed a longer time and have been recovered. I think I have seen it somewhere asserted—it is a very interesting statement, but I cannot recall at this moment my authority—that there have been cases in which persons have been immersed for a considerable time and recovered. And this explanation has been suggested; that these were probably timid, weakly people, and the suddenness of the danger had caused fainting, and consequently all the processes of life being brought almost to a standstill, they could for a longer time than usual dispense with the aid of oxygen. For the correctness of this opinion I am not prepared to vouch; but, at all events,

it affords sufficient reason for long-continued efforts to recover people apparently drowned, even though they may have been immersed for a long time, a time more than sufficient, as we may think, to cause death.

Now is it not strange that this element, without which we cannot exist for five minutes, is mainly employed in carrying on the work of destruction? Oxygen within and without the body is actively engaged in changing all substances that it can affect. The oxygen entering into combination with the tallow, for instance, the candle gives out flame and heat. The oxygen entering into the body from without, seizes on certain of its constituents which it disintegrates or breaks up, producing what Liebig calls *cremacausis*, or a slow combustion, in which heat and force are evolved. You will not wonder very much at this, when I remind you that it is by this wasting of the body that the available heat and force are produced. When we remember that a certain amount of force is needed for the maintenance of life, for breathing, for digestion, and for all the different functions that are performed in the body, as well as for all the different actions performed by the body, and that this force is gained by expenditure of substance—we can understand the value of oxygen the destroyer; for this destruction is actually the process of living, just as the burning of coal is the production of heat. Oxygen is to certain contents of the organism, in a very

precise sense, what it is to fuel. It is not enough that I have coals in the grate. If I do not supply the combustible material with atmospheric air, the fire will be extinguished in a short time. The draught or supply of air is as essential to the continuance of the flame as the fuel that is supplied. In the same way we must have oxygen carried into the body in order that its work may be done, that its heat and force may be sustained without intermission. And it is circulated, as I have said, by means of these little red corpuscles, which carry it to every part of the body where there is work for it to do.

There is one fact of some importance that has been established, I think, beyond contradiction, in connection with this, namely, that these red discs or corpuscles are very much altered by the imbibition of large quantities of alcohol. It has been ascertained that they are shrivelled and shrunk, and in many cases broken up altogether in the case of those who are in the habit of using large quantities of alcoholic liquor. And this may be one of the reasons—I believe there are many—why alcohol, which seems so useful in maintaining heat outside the body, fails to raise the temperature within it. If I put alcohol into a spirit-lamp, I get a strong heat. If I put it into my own body, I lower the flame of life instead of heightening it. We know that by the thermometer; it is not in dispute at all. By placing the thermometer under the

tongue, we can ascertain the temperature of the body. We know that in ordinary circumstances its temperature is about 98°. If we take two or three glasses of brandy, and, after sufficient time has been allowed for diffusion, introduce the thermometer again, we find the heat has sensibly decreased. Instead of the body being raised in temperature by the introduction of alcohol, it has been lowered in temperature. May this not be one reason? Although it might be useful as fuel, it damps the flame by lessening the amount of oxygen, in diminishing the carrying power of the blood corpuscles. At all events, it can be proved that, instead of making us either stronger or warmer, it measurably makes us weaker and colder.

I am quite aware of this fact: if any one feels chilly, and is suffering from the effects of a lowered temperature, a glass or two of grog warms him at once; he feels a great deal more comfortable after he has taken the liquid than before. I am quite prepared to hear any one who has made the experiment say, "That seems to contradict your explanation." Well, now, let us look at the fact; for I admit it to be a fact, and I have a great dislike to breaking my head against facts. Suppose I take a glass of brandy. Any of you watching my face would notice that my cheeks become flushed, showing that the blood begins to course more freely through them. Unfortunately, I am not a good subject for this experiment, because

my cheeks are not very pale at any time ; but there are some in whom this is wonderfully illustrated very frequently. At all events, when we take alcohol in this form into the body it increases, in some way or other, the flow of blood to the surface.

There is another fact, which I have not told you, and which I must state now in order that you may understand this result. We have in the circulation two currents. We will say an up-line and a down-line, the goods coming by the up-line and the empties being sent back by the down-line. We have supplies of nutriment carried to the city by the up-line and then we have the waggons sent down with returns of some kind, or sometimes empty, to bring us further supplies. In the same way the heart is continually sending out the nourishing blood that it has received from the lungs, sending it through the body by the arterial circulation, and receiving it back by the down-traffic through the veins. We have these two lines, and just as in the railway system we have, in connection with the traffic, special telegraphic wires that are employed to regulate the traffic, so we have along with the circulation special telegraphic wires, or nerves, to regulate the supply of nutriment. One of these is associated with every vessel, large or small. We have little twigs going out to regulate the contents of these vessels, so that they are adapted to the necessities of the traffic as direction may be given. These nerves

employed in this way can be acted upon by certain substances, and we know definitely that alcohol is exceedingly powerful as a paralyser or deadener of nerve action. When we introduce alcohol into the body, it somehow acts on these nerves that are in connection with these blood-vessels. These nerves act on the vessels which are under the skin of the cheek, for instance, retaining them in a certain state of tension or tightness, only allowing a definite quantity of blood to pass. The alcohol deadens the nerve and paralyses this power, so that they no longer keep the vessels thus tightened, and in consequence they are relaxed and open more freely. In other words, there is a larger and freer supply of blood allowed to pass into the small vessels under the transparent skin of the cheek than there was before. You have no more force applied to the heart. People used to say that alcohol made the heart beat more strongly. It makes it beat quicker by taking off, as I have explained, the restraint on the flow; not by giving force, but by arresting the action of the nerves that tighten the small vessels. The red blood freely courses under the transparent skin, and the increase in the current is seen in the flushing of the face. The warm blood being in that way sent out freely to the exposed surface of the skin, of course I feel warmer. I am externally heated by the warm flow of blood over the surface of the body; but what takes place afterwards? The cold air meets

the warm blood thus thrown to the surface. It is a provision of nature that when I am exposed to cold, in the first instance the blood is sent in from the surface, in order to maintain the heat of the body. I reverse the process, and send the warm blood out to the surface and expose it to the cold air by means of this action of the alcohol.

Suppose I am travelling on a very cold night in winter by an express train. We come to a station. I notice that the refreshment-room is open, and I rush in to get a cup of hot coffee. When it is brought to me I find that it is almost boiling, and that I cannot drink it without scalding my lips. The guard rings the bell; the train is ready to start, and I have no time to lose. I want to take as much of the warm coffee as I can, but unfortunately it is so hot that I cannot drink it. What am I to do? I pour it out of the cup into the saucer, back into the cup, and back again into the saucer half a dozen times, and then it is cool enough for me to drink. I have thus exposed the contents of the cup to the surrounding cold air, which has taken up a large measure of the heat, and made them drinkable. So when the blood is sent to the surface, giving indeed a temporary superficial warmth, the cold air carries away a certain amount of the heat, and the blood is sent back chilled and lowered in temperature into the inner part of the body, and when I think I am made warmer I am in reality made colder.

I find that I have not finished my subject, but I have finished my time. Well, we have the blood conveyed from the lungs, containing this oxygen, to the left side of the heart. In the left side of the heart it is received in the upper chamber, and is sent from that down into the lower chamber. In the heart we have provision made so that the blood passing from one chamber to another does not return. We have different kinds of valves that prevent the regurgitation or flowing back of the blood, between the two chambers on each side of the heart. We have them also in openings into the large vessels leading out of the heart. Coming into this lower chamber of the left ventricle, it is sent by a strong impulse into the aorta, the large blood-vessel springing from the heart, which, forming an arch, gives off branches to the head and arms, and then descending into the lower part of the body it bifurcates or divides into two large branches, one of which goes to each of the lower limbs. Each of these branches divides and subdivides until they become hair-like or capillary ; and then these capillaries form larger and still larger vessels called veins, in which the blood is carried back again to the heart. I have thus given a short outline of the course of the circulation.

Now we do not know much about the forces that keep up the circulation. At all events, I do not think physiologists have come to any conclusion that is not

at least open to dispute. There can be no doubt that the impulse of the heart has a great deal to do with the circulation. So far as we know, mainly, if not altogether, this impulse is the cause of the circulation. But there are some who do not accept this statement. They imagine that there must be other forces at work. At all events, we know that that impulse is sufficient to circulate the blood in the vessels during the greater part of their course. The arteries themselves are elastic and also contractile, so that when the heart sends the blood out into the aorta, it is urged onward in a wave-like manner. Consequently, if an artery is cut the blood comes out in jets. This is a recognisable distinction between wounding an artery and wounding a vein. The blood oozes out from a vein in a more or less sluggish manner. Wounding an artery is a dangerous thing, because the flow of blood from an artery is not easily arrested ; the blood flows with such force that there is no pause for coagulation or thickening. When blood is exposed to the air for a short time it coagulates—that is, it separates into two portions, one solid, the other fluid. The bleeding stops when the blood clots ; the clot forms a natural plug and stops up the end of the vessels, but that cannot take place in such vessels as arteries when the blood is jetting forth freely. When they are injured in this way the blood spurts forth with considerable force ; but if a surgeon is called in, he can lay hold of the mouth of

the vessel and tie it, and in that way stop the bleeding. When the artery is tied the upper part sends out branches, and a curious anastomosis (forming of a new network) takes place, and new branches are made, so that the nourishment is carried on as before, and there is no harm done.

In this way the blood is conveyed by the arteries right on until it comes to the capillaries, and from these it is taken up by our old friends the bioplasts, in order that they may perform their task in forming tissue. Then when these tissues are broken up, as they are by the oxygen, the waste material is carried back partly by the veins, and partly by the lymphatics I have spoken of, and returned to the upper right side of the heart, along with the chyle that is brought from the intestines : whence the process is repeated over and over again.

At any one time we have about ten pounds of blood in the body, and in the course of a year more than three thousand pounds of blood pass through the system. In one sentence, I may sum up the story of the circulation.

The blood is sent from the *right* side of the heart into the lungs, and is returned to the *left* side of the heart ; from thence it is sent by the arteries throughout the whole organism, these arteries ending in the capillaries in which the minute distribution is effected ; the blood left in the capillaries is assembled in the

veins, by which it is restored again to the left side of the heart ; and from the heart the current sets forth continuously so long as life lasts.

V.

REMOVAL OF WASTE AND NOXIOUS PRODUCTS.

IN the case of a man weighing 140 lbs., we find that he introduces into his body, in the course of one day of twenty-four hours, upwards of 7 lbs. of substance. During the same time he excretes or removes from his body 7 lbs. of substance. For it is quite evident that, were it not for this removal, the body would grow exceedingly in weight and in bulk. Why, in the course of twenty days he would add as many pounds to his body as he originally possessed ! So that we have the balance maintained, so long as we remain the same, between what we call the *ingesta*—the things taken in ; and the *excreta*—the things given out. Within certain limits it is possible that a man may increase somewhat both in size and in shape ; but even though he does reach the proportions of a Daniel Lambert, with a weight of 20 to 25 stones, he finds that he at last reaches a limit beyond which it is impossible for him to proceed. We may introduce into the body a very large amount of material, but beyond a certain amount we are unable to make any

profitable use of it within the body. I am speaking now of adult life. Of course, in childhood and youth there is a certain amount of increase available for purposes of growth and development.

Now, of the amount that we take daily, these 7 lbs.—no less than somewhere about 5 lbs., rather more than 5 lbs., I should say nearer 6 lbs.—are made up of two elements—one drawn from the air, and the other from the clouds and the springs. Oxygen and water form nearly 6 lbs. weight out of the entire amount. And when we come to the excreta we find that water and carbonic acid gas together form in like measure a very large amount of that which is thrown off.

We have already found, in following the course of the blood, that in the lungs a very large amount of oxygen is taken in ; and we have incidentally noticed that a large amount of carbonic acid gas is thrown off. We have to attend to-night rather to the latter fact than to the former. In the liver, too, we have already found that bile is produced, which is largely used, so far as we can determine, in the preparation of certain elements for ultimate absorption or assimilation into the body. We have now to learn in addition that the liver exercises another function, concerning which we have not yet reached very definite knowledge. We know that part of the bile, at least, is used in the removal of the waste materials from the

lower end of the alimentary canal. Then we shall find further that the kidneys, situated near the spinal column, in front of the lumbar region, are employed in removing certain waste or noxious products from the blood, and preparing them to be discharged from the body. Then we shall discover, in addition, that the skin, while it has other and very important functions, largely serves the purpose of an excretory organ, and gives off water and carbonic acid gas mainly, in definite quantities. Indeed, we find also that any of these organs may act as a substitute for any of the others to a very remarkable extent. We should not think, for instance, of the skin, as having anything to do with the function of breathing; yet you may remove the lungs from a frog, and it will continue to live for a considerable time by the respiratory action of the skin. In that animal the skin can perform vicariously the function of the lung, and serve to maintain the animal in existence for some time.

All these organs are employed in removing what I have called, "Waste and Noxious Products." Perhaps we may sum them all up in one term, "noxious." For when we have done with them—when they have served their purposes—they become hurtful and injurious if allowed to remain. We must get rid of them in some way or other, and by the functions which these different parts of the body perform we have them removed readily and freely as required.

Perhaps I had better begin by talking particularly of the work done by the liver. It is one of the largest organs in the body, and is situated on the right side, below the right lung, and extending partly over the upper part of the stomach, immediately under the diaphragm or midriff. We have it divided into two parts, or lobes; and when we examine it minutely, we find it is composed of a great many little lobes or lobules, and that its structure fits it marvellously for accomplishing what may be roughly termed a process of vital filtration. It is provided with a pear-shaped reservoir, called the gall-bladder, in which it stores up for ready use the *bile*, which, as everybody knows, is the name given to the fluid it secretes. This reservoir lies under the liver towards the lower right extremity of that organ. The liver itself forms and gives off, as it is needed, its own peculiar secretion; but it has also this storehouse into which it pours a reserve supply that may be drawn upon for special purposes.

I have said that the liver has another function, in addition to that which I am speaking of as the removal of waste and noxious products. Some of the contents of the liver are thrown into the intestines—into the upper portion, the duodenum—to take part in preparing the food for its assimilation. We have already noticed² that particular action of the bile, and

² See Lecture III., p. 73.

I do not need to go back upon it. Some of it, however, remains in combination with the excrementitious or unassimilable parts of the food, and is carried onwards and downwards into other parts of the intestine ; and there it seems to act as a stimulus to the action of the lower part of the alimentary canal, and to aid in the expulsion of what has been called by Liebig, I think fairly, "the soot of the furnace." We are apt to think that the waste matter of the alimentary canal constitutes by far the largest amount of the waste products of the body. It is not so in any sense whatever. It is a very small part indeed, and yet it is needful that it should be regularly removed. As the soot would clog up the chimney and lessen the draught of air, thus hindering the fire from giving forth as much heat as it might otherwise do, so our carelessness about the removal of these unassimilable materials from the alimentary canal may prevent the enjoyment of full life, and the healthy, vigorous action of the whole frame. To some extent, as you are aware, this process is under the control of our own will. The action of the liver in forming bile is not controlled by the will. The action of the kidneys in secreting their product is not under the control of the will. The action of the skin is not under the control of the will. But the final action of removing the waste matter from the alimentary canal is under the control of our will to a very considerable extent. And I believe this is of great importance in

connection with the arrangement fixed for getting rid of these unassimilable materials. I believe we can largely form the habit, and appoint the time whereby and when these waste products may be removed. Allow me to assure you, that it is most important and advantageous that we should form the habit, and maintain it, of allowing these waste materials to be removed at one particular time in each successive day; and that so soon as we have formed this habit we have gained a very valuable power over this action of the alimentary canal. A great many illnesses and inconveniences result in ordinary life from inattention to this fact. There is no condition of the alimentary canal that is more complained of than constipation, and the only effective way to guard against that is by *training* the alimentary canal, in this respect, to do its duty faithfully and regularly. That is, to a much larger extent than most people suppose, fairly within our own power. All the valuable recipes that are frequently urged upon our notice may be summed up in three words—STATED PERIODICAL ATTENTION. If you adopt this hint, you will soon find that stated periodical ACTION will become habitual. And it is a very hurtful practice, a very foolish and mischievous practice, to be having recourse continually to purgative medicines for the performance of this function, which can be managed more healthfully, more easily, and more safely in the way I have indicated.

I do not dwell longer on this subject, because, although it is important, it does not really occupy the same platform of importance on which the other excretory functions stand. Attention is very often given to this action alone, and it is supposed that if we are careful therein we need not be very much concerned about other excretions. That is a very serious mistake. A very few ounces only of waste is removed from the body by this process. By far the larger proportion has to be removed by the kidneys, by the lungs, and by the skin. And our attention must be carefully given to the action of these organs, if we would maintain due proportion, and if we would secure vigorous and enjoyable health.

I may speak next of the excretory function of the lungs. We have already considered the action of the lungs in one specific direction. We have learned that oxygen comes in contact with the blood, and is taken by it and introduced into the current that, coming from the right side of the heart, returns to the left side of that organ and is thence distributed throughout the body. We have now specially to note that this blood coming from the right side of the heart contains a certain amount of carbonic acid gas. This has to be got rid of in the lungs, through the process of which I spoke in my last lecture—the familiar process of breathing. In breathing we perform two acts; we take in something, and we give out something. The

one is no less important than the other. Indeed, it has not been settled up to this moment, whether or not it is more injurious to increase the amount of carbonic acid gas, or to lessen the supply of oxygen. A quotation from a well-known and valuable discussion of physiological questions will best illustrate this statement. "Atmospheric air contains only 21 per cent. of oxygen. But if 50 per cent. of oxygen be mixed with 50 of carbonic acid, a warm-blooded animal is suffocated in it, in spite of there being more than double the amount of oxygen present in the ordinary atmosphere. Bernard, who made the experiment, thinks that the carbonic acid in this mixture prevented the oxygen from entering the blood, not only because of its greater solubility, which gives it a tendency to displace the oxygen, but also because of the obstacle it presents to the exhalation of carbonic acid. On the other hand, the careful and extensive experiments of Regnault and Reiset show that respiration will take place quite well in an atmosphere which contains as much as 23 per cent. of carbonic acid, if at the same time it contains as much as 40 per cent. of oxygen. How are we to reconcile such facts as those just cited? In the one case, we see that 50 per cent. of oxygen is insufficient if the amount of carbonic acid be also 50 per cent. ; in another case, we see that 40 per cent. of oxygen suffices, if the carbonic acid do not exceed 23 per cent. : and we would explain both

by saying that, unless the amount of oxygen nearly doubles that of carbonic acid, respiration is impossible, were it not for the irresistible objection that reptiles breathe in an atmosphere which has become charged with carbonic acid, and has gradually lost all but three percent. of oxygen.”¹ At all events we are sure of two things: We require to have a very large supply of oxygen, and we require also to be able to exclude and get rid of the carbonic acid gas freely and fully, if we are to maintain the health of the body. Retaining or breathing this gas is mischievous in a very high degree.

I do not need to enforce, as I have taken occasion to do that already,² the importance of taking care that the atmosphere we breathe does not contain a large amount of this carbonic acid gas. I remember well what occurred on Friday, 2nd December, 1848. On that night the steamer *Londonderry* was crossing from Ireland to one of our ports here, with a great many passengers on board. During the transit, the weather became heavy, and the captain afraid that the passengers might suffer inconvenience, and perhaps that some of them might even be washed off the deck by the waves, which were breaking over the bulwarks and paddle-wings, ordered them all below. If I remember rightly, there were about two hundred on board. The

¹ Lewes's *Physiology of Common Life*, vol. i. p. 381.

² See *Studies in Life*, p. 160.

steerage passengers were ordered down into a cabin of very small dimensions.² After having had them shut up there, and still caring for their comfort, the captain ordered a large tarpaulin to be thrown over the only means of access to the cabin. The consequence was that next morning some seventy or eighty of them were found dead or dying. They were poisoned by confinement in this close atmosphere with its limited supply of oxygen and its steadily increasing enormous excess of carbonic acid. Now it may not be possible for us, with our present knowledge to tell exactly whether the greater mischief resulted from the absence of oxygen, or presence of carbonic acid. But we know that it is important that we should have enough of the health-giving, vital air, and that we should not retain or receive back again the enfeebling, deadly gas.

Some years ago our medical friends spoke out plainly and forcibly against tight-lacing. Wasp-like waists may seem beautiful to the beholders, but they are certainly not wholesome to the possessors. They tell of lessened vital capacity in the chest. I have no intention, however, of reiterating warnings that are scarcely applicable to young men. My allusion to the subject is only intended to enforce upon you in an emphatic and memorable manner the necessity of allowing free play to the internal organs, and to plead

² The cabin was 18 feet long, 11 feet wide, and 7 feet high.

especially at present for the unhindered expansion of the lungs. Please to note that nothing should be allowed to limit their mobility. Indeed the whole trunk should be free, that their action may be unfettered. Restriction or tightness in any part of the body is in ordinary circumstances an evil. And although it may seem to some a trivial thing to call attention to an apparently insignificant detail in dress, yet I do not hesitate to do so, because in my judgment it is not unimportant.

Without presuming to prescribe any particular form of garment, I insist that all garments should fit the body so loosely or easily that all movements may be natural and unrestricted. More mischief results from the neglect of this precaution than, without tedious explanations, I could induce you to believe. But, at all events, you can understand that narrowing of the trunk and preventing freedom of action in any part of the breathing mechanism must, of necessity, interfere with the receipt of oxygen and discharge of carbonic acid.

This is not merely a question of more or less comfort, it is really a question of physical well-being and vigour. When we lessen the capacity or muscular elasticity of the chest, we are restricting our gaseous income and expenditure, just as really as if we were shutting ourselves up within a limited area. Some have larger lungs and some have smaller, and we must

do the best we can with what we have got. But let us not, by any careless or foolish conduct, do anything that would lessen the usefulness and activity of such lungs as we have. Depend upon it, the measure of our efficiency and joyousness will be largely determined by their free and vigorous play.

We may now proceed to consider the action of the kidney. This organ does not remove merely the excess of water that may be present at any time ; it separates water, holding in solution a certain salt called *urea*.

This salt is the result of decomposition, and is produced by the wasting action of tissues in which nitrogen forms a leading ingredient. Speaking broadly, the amount of urea excreted may be taken as a measure of muscular waste. I shall not trouble you with any anatomical details of the structure observed in the kidney. Suffice it to say, that it has an outer bark-like substance (cortex) and an inner arrangement of multitudinous little tubes (medulla). The blood, which is conveyed to it by an artery called the renal artery, is submitted to a peculiar process of filtration for the removal of the waste material of which I have spoken. The artery, on entering the kidney, subdivides into a vast number of little hair-like vessels (capillaries), which are again massed in a vein, by which the blood, having parted with some of its contents, is restored to the circulation. We find that

the *vein* in which the blood is returned from the kidney contains the purest blood in the body: there is a marked diminution in the quantity of urea it carries. So far as can be determined, this salt is removed from the blood by a special process called *dialysis*. I shall endeavour, in a few simple words, to indicate the nature of this process. In some cases of sudden and suspicious death, when there is reason to think that poison may have been administered, it is usual to examine the matters contained in the stomach and intestines of the dead body for traces of the suspected poison. Let me suppose that, in a specific case of somewhat sudden death, we have grounds for suspecting that a soluble salt of arsenic has been administered during life. We have submitted to us the whole contents of the stomach—a very miscellaneous, grumous mixture, with which it is not very convenient to deal. Can we, without risk of defeating our object, reduce these contents to a simpler form, in which we can with equal certainty and greater facility prosecute our investigation? The answer to this question has been supplied by a series of interesting experiments conducted by the late Professor Graham. He found that it was possible to separate with great accuracy certain substances that were mixed together in one fluid mass. This separation, which he styled *dialysis*, depends on the fact that animal membranes in contact with fluids allow some

substances to pass through them and do not allow other substances so to pass. Substances readily soluble pass easily, while glue-like substances, commonly termed *colloids*, are scarcely diffusible at all. We take, then, the whole mixture submitted to us, and enclosing it in an animal membrane, such as a bladder, we suspend it in chemically pure water contained in a jar. Within a short time the soluble salt of arsenic, if present, will pass through the membrane into the water, where we can subsequently find it by the application of the usual tests, while the colloids or glue-like substances remain enclosed within the animal membrane.

It is supposed that in some such fashion the kidneys act on the blood that passes through them—that they dialyse the blood, leaving undisturbed the other contents while secreting certain portions of the liquid containing urea and some other substances in solution. This separated fluid is carried by little tubes called ureters into a reservoir known as the bladder, from which it is in due time passed along another tube and expelled from the body.

As I have said, these and other organs employed in removing waste products are to some extent vicarious, so that the liver, for instance, may compensate partially for the sluggishness of the kidney, and the kidney may compensate for the sluggishness of the liver. There is a margin of this substitutional action

by which one organ may relieve another, if that other happen to be inactive or overworked. We have a familiar example of this substitution in the increase of skin-action during warm weather, with corresponding decrease of kidney-action; and the increase of kidney-action during cold weather, with the corresponding decrease of skin-action.

We may, at this stage, pass naturally to a consideration of the skin as an excretory organ. The skin is composed of, and conveniently divided into, two layers—the scarf-skin, the external covering which we touch and see, and which we know to be destitute of sensibility; and the inner or true skin, which is very sensitive. I am not going to talk to-night about the nerves of feeling which have their seat in the skin; the study of them must be deferred until we are prepared to consider the “special senses.” I have to speak to-night simply of the excretory functions of the skin. I hardly think that it would be possible to give you any exact idea of the number and arrangement of the tubes that are contained in the skin. Dr. Erasmus Wilson calculates that united they would form twenty-eight miles of tubing. I am not sure that we get any real idea of the action of the skin from an enumeration of these miles; but we have a fair idea of its work and of its importance as an excretory organ when we remember that it removes about two pounds weight of matter daily. The outer,

visible part of the skin is formed of scale-like cells pressed together, and, if we examine it microscopically, we find that as it deepens we reach a point where these bioplasts, of which I have spoken frequently, begin to appear and act. Nails and hairs are simply skin-appendages. They are of the same structure as this outer skin, slightly altered for particular uses. So too are the horns of animals. One reason why the true skin has this outer covering or coat of non-sensitive material is evidently that it may be protected. Thereby the inner and particularly sensitive layer is saved from rude contact with the outer world. At the same time, we must confess that there is a slight disadvantage in this covering, and the disadvantage is unnecessarily increased if we allow an excessive amount of these scale-like cells to accumulate. They are literally being continuously produced and thrown out by the living action within, and it is desirable that the old layers should be removed as the fresh layers are formed. If the layers become numerous, not only do we blunt the sensibility of the surface, we also obstruct the action of the excretory glands that are employed in the important task of removing effete and noxious substances. These excretory glands are called the sudoriferous or sweat-producing glands. Associated with them we also find in the skin the sebaceous or oil-glands. These oil-glands produce a substance that keeps the skin flexible,

and which also keeps the hair in a healthy and proper condition. We find them in large proportion in certain parts of the body where they are most wanted, and in other parts they are almost entirely wanting. The sweat-glands we find distributed very fairly over the whole of the body. In some places we find them in larger quantities than in others—for instance, in the palms of the hands and in the soles of the feet ; and they are almost entirely absent from the back of the neck. When we examine the substances they secrete or separate, we find them to be water, carbonic acid, and certain salines. These substances are contained in the fluid perspired. Perspiration is recognised under two conditions—sensible or insensible. It is sensible during excessive heat or when we exert ourselves violently ; for in these circumstances large sweat-drops stand on our brow or begin to form and flow along our limbs. It is insensible at ordinary times, but no less real ; for there is always more or less of this watery exhalation passing from us into the atmosphere in the form of invisible vapour. The dryness or humidity of the atmosphere must, of course, largely affect this transference : dry air inviting it and humid air repelling it. On the importance of fully maintaining this function I need not dilate. If the skin be inactive, then either other organs are burdened or waste matters are retained. In any case, mischievous results are not slow to follow.

In this connection I may call your attention to another purpose served by perspiration. It aids materially in regulating the temperature of the body. In very warm weather, or when we are exposed to a strong artificial heat, the perspiration comes readily to the surface and we are cooled, not as if water were poured over us, but by the gradual evaporation of this fluid that has been thrown out. There is no more effectual method of cooling the surface and reducing its temperature than this. The intense cold produced by evaporation has been used in some instances by dentists to lessen sensibility in the pain of toothache, or to deaden the nerve filaments preparatory to the extraction of a tooth. We can, by evaporation from the surface, lower the temperature of the body very decidedly. And in warm weather, especially during exertion, the perspiration being evaporated by the heat of the air, the temperature of the body is very pleasantly reduced. There is admirable provision made for maintaining its animal temperature equably in many different conditions. In the Equatorial and Arctic regions we find that the human body maintains very nearly the same temperature. In the one case, the temperature of the air is higher than the natural temperature of the body; and in the other case, it is more than 100° lower. Yet in both cases the bodily temperature is maintained at the normal standard. And one of the means whereby this maintenance of

the normal standard is secured in hot climates finds its explanation in the evaporation of the watery products of the sweat-glands.


Now there are some who perspire more freely and readily than others. That may depend to some extent upon individual constitution. It may depend, for instance, on special nervous action. But, in addition to these cases of difference, there is something to be allowed for the condition in which the skin itself is maintained. If we allow the pores or outlets of the sweat-glands to be closed or obstructed by "matter in the wrong place," we must of necessity interfere to some extent with this natural and needful process. There are many evils that result from this carelessness about the condition of the skin, and I will venture to recommend one method of setting it free for the discharge of its duties. Before doing so, permit me again to insist on the importance of this great excretory organ of the body—I call it great advisedly. At the coronation of Pope Leo X. a little child, intended to represent an angel, was covered all over with gold leaf. The child died within the space of a few hours. The skin was hindered from doing its work, and death resulted. In some experiments, animals have been covered over with impervious material, that allowed no action of the skin, and no escape of anything from the surface. They always died within a short time. And this very remarkable fact was noticed—that the

temperature invariably fell. At first one might be disposed to think that it would rather have been raised by covering the skin, when we remember that the outer air with which we are familiar is ordinarily colder than the body. The heat of the body is about 98° to 100° , whereas the outer air in this country is seldom more than 70° or 80° . We put on clothes and coverings of different kinds, not to make us warmer, but to prevent the body from being chilled by the abstraction of the heat which it generates. If I put on some impervious covering so that there is no escape of the heat, one would think I should become warmer, but it has been found that the temperature falls to a very large extent. This fact seems to indicate that the skin has other actions with which as yet we are not acquainted. I believe that it performs other functions that have not hitherto been discovered. Probably it has more numerous relations to the world outside than the wisest among us have yet imagined. At all events, we are sure of this, and we know it from practical experience, that this extensive and important organ should be preserved in thoroughly good working order. It may be pertinently asked here: Ought I to take a cold bath every morning? Yes, if you like it. I do not choose to take one. If individuals find themselves refreshed and invigorated by a cold bath, by all means let them have it; but I do not find that for all constitutions a cold bath is either pleasant or

healthful. There are some of us who cannot benefit by the protracted application of cold water, not because we have any objection to the bracing effects of cold applications, but our power of evolving heat is not sufficient to overcome readily the depressing effects of immersion, even though it be of short duration. There are some people who come out of a cold bath with their fingers bloodless and their teeth acting unpleasantly as castanets; their vitality has been unmistakeably lowered by the reduction of their animal heat, and it is not sufficiently restored even by vigorous rubbing with a dry towel. I think that there has been an exhibition of some foolishness both in the use of cold water and in the praise of cold water; so far, at least, as its application to the body is concerned. Mark you, I am not saying anything against water. I am speaking about the temperature of water. Indeed, you may take a cold bath every morning and yet not keep the skin in a very healthy condition after all. Water alone, especially cold water, does not remove the waste and other material from the skin. If I were to wash my face simply in cold water, I should not look very bright at the end of the week. We use in addition a very valuable preparation called soap (with which, I presume, we are well acquainted), which acts chemically on the substances that ought to be removed and facilitates their removal. And, on the whole, I find it most agreeable and, I think, most

useful, to apply the water at a temperature nearly equal to that of the body itself. We may regulate the temperature very much according to our feelings. Water thus applied to the whole surface once a week or oftener, as circumstances demand, will be found fairly adequate to the maintenance of the skin in a state of healthy activity.

I may mention one other thing, simply by way of addition. In some cases, and especially in some cases of disease—although I am not dealing with disease in this course—it may be advisable to have recourse even to more active measures with the design of exciting the excretory function of the skin more decidedly. For that purpose, I do not know any more valuable agency, *under proper direction and used with due caution*, than what is commonly known as the Turkish bath. I believe the liver is blamed for a great deal of mischief it never does. If people get out of sorts in any way, they are almost sure to say that their liver is out of order. I think that this unfortunate organ gets a very large amount of blame which it does not deserve. The truth is, that what are commonly called bilious complaints are simply cases of indigestion, and could be got rid of most easily, although, perhaps, not most pleasantly, by a little course of starvation. Some people are very much afraid of lessening the amount of food they take. Now, I believe that there are very few indeed who do not regularly eat too much. At



all events, it is very safe, if we are in ordinary health and are suffering from any derangement of the digestive organs, to give them rest. I do not know a more valuable healing agency in such cases than rest. But in any case in which the *liver* is really at fault, when it is either sluggish or imperfect in its action in consequence of being overtasked, the Turkish bath will frequently be found to act wonderfully in giving it relief and enabling it to resume its healthy action.

By means of it, particularly by the profuse perspiration it excites, you can *flush the sewers*, and hurry out stagnant, hurtful deposit. I may add that what is known as the wet-pack, with attention as before hinted to the temperature, is a valuable adjunct.

I daresay you have noticed after taking a bath that the feeling of thirst is sensibly reduced. This fact is suggestive (though I do not enlarge upon it) especially in cases of excessive thirst. Those who have been at sea, after shipwreck, and having no water—and, of course, knowing it would be dangerous to drink salt water, as that would only increase their thirst—have got relief by wetting their clothes with salt water. This, however, is only safe practice when they are able at the same time to maintain their temperature by food, etc. ; otherwise the cold application and subsequent cooling by evaporation may hasten death by lessening their animal heat.

I have not been in the habit throughout this course

of saying anything about the indications of Divine wisdom or goodness in the structure of the body, simply because, in my judgment, that man studies physiology with very limited intelligence, who does not come to the same conclusion as that reached by the old Greek physician: "The human body is a hymn of praise to its Maker."

VI.

THE NERVOUS SYSTEM.

YOU are all familiar with the old story of the shield composed of two materials. The knights approached it from different directions ; one of them saw a golden shield, and the other saw a silver shield. They disputed as to the structure of this piece of armour, and, as the story goes, they at length came to blows. We are told that they might have settled their dispute very readily, if each one had passed round to the point of view occupied by the other. It is sometimes said that disputes between philosophers and physiologists are of this kind. We look at the subject from two different stand-points, and if we changed our mode of examination we should be likely to arrive at an ultimate complete agreement. Nowadays, we are told something more. It is maintained that just as that shield had two sides, so has nervous matter, or, indeed, matter of any kind. It is asserted that nervous matter has two sides—an upper and an under, a mental side and a material side. We are told not only that matter has in itself the potency of


life, but the potency of *all* life, and that intelligence and will are as much properties of matter as growth and development.

In this lecture I have to speak of this wonderful substance in which these distinct qualities of matter are said to exist in this wondrous unity. And I venture to say, before proceeding further, that for my own part, I have never been able to discover the mental side of matter. I should not be at all shocked if it were proved to me that from brain or nerve, ideas, memory, emotion—all that we understand by intellectual life—may as really be developed as motion from muscle. I think I could maintain all that is vital in my relation to God and my fellow-men, in spite of that startling discovery. So that it is not because I feel that there is any irreconcilable antagonism between this form of materialism and the religion which I cultivate, that I am prepared to vindicate my doubt and disbelief. My rejection of this double-aspect theory of matter rests on very simple and intelligible grounds. Just as we found that we could not explain the action of living things, without predicating something more of them than was possessed by dead matter, and just as we were constrained to give the term “life,” the only fitting word, to this something more ; so I predicate “mind,” when I witness actions performed that indicate purpose and will—of which purpose and will I am personally conscious as determining my own conduct.

Some years ago, a certain school of philosophy made the discovery that the attempt to find out the laws and operations of mind, by examining our own consciousness and by studying the records of the consciousness of others, was neither successful nor sufficient. They complained that it had not led to any definite results, and they maintained that it was only by a change of front, issuing in the confinement of our investigations to an exact examination of the physical structure of the organism that is concerned with the process of thinking, that we could expect to arrive at any result likely to prove satisfactory and complete. Well now, for several years the study of philosophy through physiology has been very widely pursued, but I am not aware that any very notable discoveries have been made up to the present date. I am not even aware that any very notable discoveries in connection with physiological facts have been made by our physiological philosophers. I am far from hinting that the philosopher ought not to know something about physiology, or that the physiologist might not with advantage learn something about psychology, or the science of mind. But I venture to say, that we have not had the boasted discoveries that were sure to be made produced up to the present hour. No doubt there have been certain investigations of very great interest, and I suppose there will be others of a similar kind in the future. But as to the action

of mind and the nature of mind, or, as they might prefer to phrase it, the thinking action of nervous matter and the nature of nerve-thought, our physiological students leave us as much in the dark as we were before they commenced their dissections. And indeed I cannot see how it could well be otherwise. We may examine the *instrument*, but that does not give us full-orbed knowledge relative to the operator and the operation. I think that any one who is acquainted with the movements of his own mind, and has considered them carefully, really possesses as much information in regard to these mysteries—memory, association of ideas, thought—as any one who has dissected and microscopically examined all the nervous tissues of the body.

In speaking to you of this nervous system, I may best begin by asking: What are the nerves? To this two answers may be given—one by the anatomist, examining simply their structure; and another by the chemist, examining the materials that compose them. We may dismiss the chemist's answer first. He will tell us that the nerves are composed of water, albumen, cerebral fat, osmazome, certain salts, and phosphorus. We do not get much relevant information from him. The anatomist will tell us that a nerve may be either a nerve centre or a nerve cord; that it may be a little body, or a mass of little bodies, occupying a certain definite position in the body; or it may be a thread



of communication connecting these little bodies, or larger bodies, with some other part. In other words, we have centres and conductors. Let us begin with the conductors. I dare say most of us are familiar with the general appearance of a large nerve, as it may be seen when exposed in the human body. It looks just like a white cord proceeding from one point to another. But let us not mistake this, as if it were one simple uncompounded line of communication between one part and another part. Any such nerve that we may separate, or take out and examine, is composed of an immense number of nerves, or of nerve fibres united together in one bundle. Probably many of you have seen a section of the Atlantic cable, or some other large medium arranged in a similar manner for the conveyance of electric discharges. In that section you noticed a large number of wires embedded in some material and enclosed in a protective covering. In like manner, in a so-called single nerve, such as the one we find in the fore-arm, we discover on closer examination a great many distinct fibres, corresponding to the wires of communication in the cable, which fibres are really separated one from another, while at the same time they are bound up in one common sheaf.

Let us separate one of these fibres, and examine it more minutely, by means of the microscope. We find it is composed of three parts. Let me use a com-


mon illustration to give you an idea of its structure. Take a candle and wrap round it one fold of stout paper. Lifting it thus enwrapped, you hold in your hand three distinct things,—the outer covering, the grease or wax, and the wick. So in the nerve we find that there are three parts—the outer protective sheath; an inner white substance; and an innermost rod of semi-fluid matter which is called the axis cylinder, or nerve proper. This white substance—called the white substance of Schwann—seems to act as an insulator, preventing the axis cylinder from misdirecting, or spending valuelessly, its energy. What I have called the nerve proper, the innermost substance, is used for the purposes of nervous communication, and corresponds in position to the wick of the candle. As I have said, this is not solid but gelatinous. When it is freshly taken from the body we find it in a semi-fluid condition.

It has been a question hotly and much debated: What is the process, the nature of the communication, that takes place along the cord? Indeed, physicists are not even agreed at this moment as to whether *electricity* is matter or force. Some hold it is material; others hold that it is simply a form of energy. You cannot therefore wonder that physiologists are not agreed as to the process or method whereby communications take place along the channel of nerve fibre. Descartes supposed that nerve-action was dependent on a nervous

fluid conveyed by this axis cylinder ; that something, which he could only speak of as a fluid, travelled along its course. Hartley, later on, described nerve-communications as vibrations. Just as we can stretch a cord from one part of a room to another, and cause a vibration to travel from one end of the cord to the other, so he thought movements travelled along the line of the nerve. Galvani thought that nervous action was electrical. That theory, though plausible, has ceased to be popular with students of physiology. For it has been ascertained that, in various important respects, there is no agreement between this nerve-force—if you will allow me to use that expression—and the electric current. Nerve-force does not respond to the ordinary tests for electricity. We can break nervous communication by tying a ligature round the nerve, but we cannot so interrupt electrical communication along a wire. Besides, electricity travels at the rate of 462 *miles* in a second, and nerve-force travels at the comparatively slow rate of 240 *feet* in a second. There is a very great difference in these and other respects between the two forces. I do not contend that there is no analogy between them, and that for purposes of illustration we may not make use of many terms derived from the science of electricity to explain the nature of nervous action. But I may say that it is almost universally admitted now, that if nervous action has any *relation* whatever to electricity, nervous force



itself is not such electricity as we are familiar with outside the body.

Later still, we find some prominent physiologists speaking of the nervous current as due to polarity. A change in the arrangement of the molecules of the nerve, similar to that which takes place in the particles of a piece of soft iron when rendered magnetic by the galvanic current, is supposed to determine their activity. Allow me to give an approximate illustration. A number of balls are placed on the table before me. One of them stands a few inches from the others which are in successive contact. I push the detached ball against the line ; the force travels along the balls until it comes to the last, which, standing free on one side at the other end, is sent off from the linked series to a distance measurable by the force applied at the other end. The arrangement of the balls is now altered. The one that was a few inches apart, is now touching the first in the series ; and the one that stood last in contact with the others, is removed to a distance of a few inches. Another and closer illustration has been put in this form. Take the two letters D, O. We may have these letters arranged in a series after this fashion : O stands alone at the beginning ; then DO, DO, DO, DO ; while D, standing also alone, brings up the rear. Now we may change the arrangement : D standing alone at the beginning, followed by OD, OD, OD, OD ; O now standing alone to close the series. So, if I apprehend





this theory of polarity, there is a re-arrangement of nerve-molecules during the passage of a nerve current.¹ I do not think that helps us much in understanding the nature of the action. The truth is that we are really ignorant concerning the *nature* of nerve-action; we only know that there is such action, and that it travels in certain directions, according to certain observed laws.

Now I have spoken already of two kinds of nervous tissue, cords and centres, conductors and—what shall we call them?—communicators. I do not know that that is a correct word to use, because we are not certain that these originate force. But for general purposes, and as an expression of a widely accepted theory, I may allowably use this term. There are many varieties of opinion held in regard to the nerve-centres. Some think that they are able to store up nervous force; some think that they are able to register impressions under certain conditions; some think that they generate the nervous force that is transmitted along the lines of communication.

A nerve-centre may be represented as a cell, thus . I suppose you are familiar, by this time, with the general appearance of a cell, as we represent it at least, diagrammatically. We have here what may be called a nerve-cell. Then I may draw a line  to represent a

¹ For a full statement of this theory, see Todd and Bowman's *Physiology*, vol. i. p. 236.

nerve-cord. Now, although these nerve-cells are of the same structure throughout the body, and the same may be said of the nerve-cords, they serve different purposes in different positions. For instance, from this nerve-cell there may be another transmitted to a muscle at this end , causing the contraction of

muscular fibres ; just as I now issue an order to my fore-finger which causes it to raise itself aloft from the other fingers. That order has come from the nerve-centre, and has been transmitted to the muscles employed in making this change in the position of my finger. Then we may also have nerves connecting the centre with the skin . And although there may be

no action *from* the centre to the skin (S) there may be action from the skin (S) *to* the centre. In the former case, we have action from the centre to the circumference ; in this case, we have action from the circumference to the centre. In the one case, we have a nerve carrying an order out ; in the other, we have a nerve carrying an impression in. Yet this nerve-centre that gives the order is the same in structure, it may happen the same identically, as the one that receives the impression ; and the cord connecting both is precisely the same in structure, differing only in its distribution. In the one case, it goes to the muscle ; in the other, it goes to certain little skin-organs that give us the sense of touch. The truth is, we cannot distinguish between nerves except by observation of

their position. We can find, by observing where they go and what they do, what the nature of their action may be, but nerve-cords or nerve-centres are identical in structure throughout the different parts of the body. The nerve that goes to the liver, giving the order to secrete bile, is the same in structure as those that go to the muscles, or those that come from the skin, or those that go to the stomach and give the order to the glands to secrete stomach juice. The nerves are the same in all their structural characteristics throughout the body, and the difference of action is simply determined by the difference of organ *to* which they go, or *from* which they come. Their relations determine their uses.

Taking the simplest form of what is called a nerve-arc, that is to say, a communication from the circumference to the centre, with a return communication from the centre to the circumference—a process round from the outside to the centre and back again to the outside—we find that many actions are performed automatically: that is, without apparent reference to any other part of the nervous system than the nerve-centre and cords concerned directly in the action. If we are on our guard against an illegitimate significance that may attach to the term “automatically,” we may use it safely and it will prove convenient.

A fly lights on the back of my hand. It irritates the skin and my hand is drawn away. I am reading a

book, or engaged in conversation at the time, and I have no consciousness either of the irritation or of the removal ; my attention has not been called to it. Yet the sensation has somehow or other reached a nerve-centre, and the order has been issued from that centre to remove this part of the skin from the influence causing it. Within the organism there are many acts of this kind continually taking place. There is one notable case that occurred in the practice of the well-known John Hunter. One of his patients was paralysed in the lower part of his body. By the severance of his spine he had no power of motion or sensation below the point of injury. But when his leg was pinched it was violently retracted or drawn away. John Hunter said : " Do you feel that ? " The man naïvely answered, " No, sir, but my leg does." And he was as nearly right as could be under the circumstances. He had no consciousness of it, because it was not translated into consciousness. It was not sent up to the certain part of the nervous system where these things are referred to distinct action, and where sensations are recognised, so that he himself was not aware of this action upon his leg ; but it was sent to a nerve-centre, and that nerve-centre immediately sent out the order to the muscles connected with the leg to remove the irritated part from the unwholesome action.

Nerves are associated both with motion and feeling. Does one and the same filament serve to move a

muscle and to excite sensibility? This question was first distinctly put to himself by Sir Charles Bell, and led him to make these inquiries and experiments which resulted in the remarkable discoveries that gave a new departure and value to nerve physiology. "Let us examine," he says, "in what direction the nervous influence which gives birth to motion must necessarily be transmitted through the entire length of a nerve so as to produce muscular contraction. Since will has its origin in the brain, and the force, whatever it may be, which acts upon the nerve must be diffused towards the muscles, it is evident that this force will proceed from within to without, or as a *centrifugal* force. But when a sensation takes place,—since the effect must be produced by the impression made on the extremity of the nerve expanded under the epidermis, and transmitted by the nerve itself to the sensorium,—it is also evident that this second force is a nervous current which proceeds from the circumference to the centre, or a *centripetal* force. In a word, the force which precedes muscular contraction runs along a nerve in one direction, and the force which causes sensation runs in another. Is it then logical to suppose that the two forces cross each other thus; that the same nerves, or the same portions of the nervous centres, exercise two functions at a time?"¹ The investigation of this sub-

¹ *Anatomy and Philosophy of Expression*. Appendix. 4th Edit. 1847. Quoted in Pichot's *Life and Labours of Sir Charles Bell*, p. 91.

ject issued in the establishment of a distinction between nerves of motion and nerves of feeling—the former being called *motor* nerves, and the latter *sensory* nerves.

At this stage I may indicate that we have two groups of nerves in the human body. One group—comprising the brain, the spinal cord, and the nerves proceeding from them—is commonly spoken of as the *cerebro-spinal axis*; the other group, formed by a series of ganglia (knot-like masses) intercommunicating by threads on each side of the vertebral column, is called the *sympathetic system* of nerves. This latter system, the sympathetic, is mainly occupied in conducting the processes of organic life. It sends branches to the large organs in the chest and in the abdomen, and also to the blood-vessels. I must add, however, that nervous influence is supplied from the *medulla oblongata* (oblong marrow), at the base of the brain, to maintain the vital process of respiration and to assist in directing other organic functions. In the medulla there is a part called the respiratory track, from which one large nerve (the pneumogastric) takes its rise, the fibres of which can be traced to the lungs, heart, liver, and stomach.

A great many of these actions that are called organic take place apart from any cognisance that we may choose to take of them, and to a large extent apart even from consciousness. I have some power over

my breathing. I can restrain, lessen, or quicken it by an effort of will; but I have no power, or very little, over the action of the heart. Emotion acts on the heart, but will or purpose does not seem to affect it much. And we have no appreciable power over such internal organs as the stomach or liver, although, in these cases also, emotions or anxious thoughts have some power, as all those who have been troubled, either by abnormal action of the liver or stomach, have learned by sad experience.

I am concerned for the present mainly with that system of which the brain and spinal cord form the leading features. We are not to suppose, however, that the other nerves in the body that I have spoken of under the name of the sympathetic system are altogether independent and separate. There are communications between the fibres of these nerves and the fibres that come from the cerebro-spinal system, and there is a unity given to the whole body in consequence. But it would appear that there are a great many nerve-centres that act readily and constantly without any need of communicating their action to what we may call the influential or the higher part of the nervous system. Permit me to remind you that we have already learned that there are nerve-centres and nerve-cords. We have now to recognise the fact that there are higher centres to which these lower centres may report, and a highest centre—the brain—

which to some extent takes cognisance of and exercises control over all. Dr. Draper, in his treatise on Physiology,^{*} suggests that these higher centres may be registering centres, and that the highest of all (the brain) constitutes what may be termed the influential arc. By this arrangement excitement of a nerve filament carried only to its own centre may simply give rise to a reflex motion ; or carried higher, it may give rise to other associated motions ; or carried finally to the brain may give rise to consciousness, and to such results as may follow therefrom. It is supposed that the cerebral hemispheres have something to do with this translation of nerve-action into consciousness. At the same time, I am anxious to guard you against supposing that we are able to account for or explain this translation. We cannot follow nerve-action into consciousness. Consciousness is a novel fact ; and it cannot be fairly spoken of as a product. Bile is a *product* of the liver, gastric juice is a *product* of the stomach—and we can trace the changes through which these products are reached ; but we cannot connect thought or consciousness with any action of nerve-fibre or nerve-cell. I must ask you distinctly to apprehend this truth, that changes in nerve-matter and emergence of thought belong to two distinct spheres—they may be in the closest possible association, but they are not commensurate ; we cannot possibly con-

^{*} Draper's *Human Physiology*, p. 280. 2nd Edit.

ceive or speak of them in the same terms. There is a chasm between them over which it is impossible for us to pass.

It may be said, fairly enough, You have material forms—nerve-centres and nerve-cords—and you admit that motion may be transmitted from the one to the other; is it not possible to enlarge your conception and to suppose that in some way ideas and emotions of different kinds may be evolved from the same materials? My objection to framing any such supposition is at least an intelligible one. We are able to trace the transference of motion from one body to another; but when we are asked to translate motion into thought we are non-plussed. Motion can be translated into heat; it can be translated into electricity; it can be translated into other physical forces of the same class as itself; but we have no experience that will enable us, for a single instant, to grasp the conception that it can be translated into thought. And I venture to say, that it is for those who maintain that this is possible to furnish us with the reasons and to formulate the method. I have read with some care many of the arguments adduced in this direction without being in the slightest degree convinced by them. Not that I am unwilling to be convinced. I would not feel that there was anything lost—I might even recognise something gained—if it were possible to translate motion into thought. But my mind, con-

stituted as it is, cannot grasp or understand the possibility of this translation of physical movement into thought or emotion.

Let me now recall your attention to those movements that are called reflex. Sir Charles Bell, examining the two roots from which the nerve—or rather the many nerves inclosed in one sheaf—spring from the central cord in the vertebral column, and are distributed to the muscles and the skin, etc., pointed out that these two roots have different functions. They have also different places of origin—one rising from the anterior or front portion of the spinal cord, the other from the posterior. By cutting across the one in front and the one behind in succession, he proved that the one was concerned with sensation, and the other with motion. By dividing the anterior or front root, he found that on stimulating the cut end *next to the vertebral column*, there was no feeling and no result; but that on stimulating the cut end which was still in communication with the fibres *leading to the muscle*, the muscle contracted. On dividing the other root—the posterior root—he found that when he excited the cut end next the spine there was pain felt; but when he excited the other cut end that was in communication with the fibres going to the surface, no feeling or action followed. He thus demonstrated a distinction which has been accepted ever since between the two kinds of nerves. The nerves of *anterior*

origin are lines of conveyance *from* the spinal cord ; they are *motor* nerves, or, more correctly, *efferent* nerves—nerves carrying out something to the circumference. The nerves of *posterior* origin are *sensor* nerves, or, more correctly, *afferent* nerves—nerves whereby impressions are conveyed *to* the nervous centre.

As I have said, we may have direct transmission of a message from the outside to the inside, and a response sent almost immediately from the inside to the outside ; in other words, the motion of the nerve may seem to be reflected or sent back again along the course of the other nerve. It is more correct to say that when the intelligence reaches the nerve-centre, immediately there is a command, or stimulus, conveyed along the line of the other nerve determining a certain result in the part to which it is distributed.

When we examine the distribution of these nerves we are unable to say precisely how they end. It is disputed whether they end free or in knots, or whether they are continuous with the structures into which they pass.

I do not know that any theory would be universally accepted in regard to nerve-action. Probably the following explanation, which you will find frequently given, is as helpful and as exact as the present state of our knowledge admits.

Let me first say, however, that a large amount of

nervous energy or action is not equivalent to a large amount of strength. There is no necessary connection between these two things. We get the force we use, as we shall have occasion to note later on, from the food we take into our bodies, conditioned by the state of the body into which it is conveyed. Any force that we may have in the nerve-current has been gained after the same fashion as the other forces that are used for other purposes. So that a man possessed of a large amount of nervous energy may not necessarily be a man of very great strength. A man might have a very active nervous system while possessing a very limited store of energy available for work. And it is easy to form the reverse conception of a large amount of work-force without proper appliances for its direction and use. We know that, if we have gunpowder properly placed in the barrel of a gun, a single spark will cause it to explode, and the liberation of the gases contained in the gunpowder by this explosion will send swiftly a solid ball of lead a considerable distance. We have these gases in the gunpowder; you may say we have got the latent energy stored up in it, but how is it to be set free and made available for action? It can be set free by fire. I take the percussion cap containing the fulminating powder and put it on the nipple of the gun, and by bringing down the hammer I at once produce the needful spark which, reaching the gunpowder, liberates the

gases, and the missile is sent in the direction desired. Now it has been suggested that the nerves do for the muscles and the secreting glands very much what the detonating cap does for the gunpowder. The liver does not act until it is stimulated ; the muscles do not act until they are stimulated. They have in themselves the power of contraction or secretion, but they require this stimulus to bring these powers into play. And it is suggested that it is by means of the nervous force or current that we are able to set free these forces either in the muscles or glands.

We can thus acknowledge the importance of the nervous system, while at the same time we do not over-estimate its value.

There are many experiments on record, proving amply enough that electrical irritation produces action along the nerve-cords. Very interesting experiments in this direction have also recently been made by Professor Ferrier in this country and Hitzig in Germany, specially locating the centres of certain actions in distinct parts of the brain. It must not, however, be concluded that these experiments give us a sufficient explanation of nervous action. I am not now questioning the absolute value of the information which may be thus gained. It is not denied that motion may be communicated to a nerve-cord by electricity or by irritation ; which motion, conducted by the fibres, produces a definite result where these fibres terminate.

But what I ask is this: How is it that the same motion originates *without* electricity, in the individual, independent organism? By exciting electrically the end of a nerve I produce the contraction of a muscle, but I can produce the same contraction without any such irritation. I can produce it by an act of will. I wish to raise my hand, and it is done almost as soon as I wish it. I can act directly upon these nerve-centres, in a way that is not explained by these electrical excitants or other irritants that are applied to the nerve-cord. Do not let us run away with the idea that, when we find in this way that motion can be communicated by other agents to the nerve-cord, we have solved the problem of the action of nerve-centres or cords within the human body. That problem remains as insoluble, or at least as unsolved, after you have made these discoveries as before you began your inquiries.

And I venture to say, that what is true in regard to motion is more abundantly true in regard to sensation and consciousness. It is generally stated in books that the cerebral mass is the organ of mind. I am not prepared to contend that this has been thoroughly and completely demonstrated; but I may fairly enough assume it as a generally-accepted belief. Admitting that brain is somehow associated with thinking, whence comes the power that calls it into activity? You tell me that brain is the organ of mind. But then, what

plays on the organ? What uses it? Nerve-matter can be excited by electricity or irritation, but what acts on it in the absence of electricity or irritation? How is it that this organ within itself (*ex proprio motu*) has the capacity of originating and expressing and recording ideas of various kinds? and how does it independently and originally excite to action? I do not think that we have got one whit nearer to any satisfactory answer to these questions after all our microscopical, anatomical, and chemical investigations. The problems remain still problematical. I am not saying that I can prove that there is a thing called mind, visible or invisible, spiritual or non-spiritual; but I am saying, that we have come to an end of our intelligence of the matter when we reach the fact that it is through the direction and use of this cerebral mass—by the *mediation of the brain* if you will—that these different results follow. The *user* and *director* we are not able to see or to describe; and yet that there is such a user or director is our earliest recognised intuition, the most ineradicable conviction we possess.

There are a great many questions suggested by the structure, arrangement, and relations of nerve-tissue that have not hitherto received full attention. What is the meaning of the marked difference in structure between the brain and the spinal cord? If you examine the structure of the spinal column you find that it is composed of two kinds of nervous matter—a

white, and a reddish-grey or ashen-coloured layer. These occupy distinct positions. The reddish-grey is inside, and the white outside. The white is fibrous, and of the same structure as the nerve-cords. The reddish-grey or ashen-coloured is supposed to be nerve-centre material, and it is in this that nerve-action is supposed to be originated or stored. When we examine the brain we find that these two kinds of nerve-tissue are placed in reverse order—the reddish grey is on the outside or surface, and provision is made for a very large amount of it in some cases, by a series of surface-foldings or convolutions; while the white tissue is inside. I am not sure that we have reached any definite knowledge in regard to the distinct uses and relations of these two parts of the two great nerve-centres—the brain and the spinal cord.

It is generally admitted that we recognise differences between animals corresponding mainly to the difference in size of brain and to the difference in form and quality of brain. I note that statement as to form and quality because some brains, for instance, may have a much larger amount of this surface brain-tissue (the ashen-grey nerve-tissue), because they are marked deeply by a larger number of these *in-foldings* or convolutions.

I do not enter into details connected with the structure of the brain. They are of no importance for our present purpose, and at present our know-

ledge of their significance is very limited. I may say here, however, that it is a favourite idea with some physiologists that mental vigour is greatly conditioned by the number and depth of the brain-convolutions. These, as we have noticed, determine the amount of surface brain-substance—the reddish-grey or ashen-coloured nerve-tissue. This surface-tissue is supposed by some to have a more immediate connection with thought and mental power; so that it has become a very widely-accepted opinion that “intellectual eminence is associated with the number and extent of the convolutions of the brain.”

While it is true that animals have their position in the scale of intelligence determined to some extent by the size of their brains, yet that is by no means to be accepted as a rigid standard. Primarily, of course, we have to take into account, not merely the size of the brain, but also the size of the brain relatively to the body. An average male human brain is about $49\frac{1}{2}$ ounces in weight. The brain of the female is 44 or $44\frac{1}{2}$ ounces. Some may be inclined hastily to conclude that woman is therefore an inferior creature, but you must remember that a woman's body is proportionately less. We find that in man the weight of the brain corresponds to the weight of the body in the proportion of 1 to 40.* In the marmozet we find that the brain corresponds to the body in the proportion of

* That is, the weight of the body is forty times that of the brain.

1 to 20. In the case of a child we find that the brain is very much larger in proportion to its body (at birth 1 to 10) than is the adult brain. It must be said, that in the case of the marmoset the convolutions are almost entirely absent, and that fact may make a difference in regard to force. But we have other cases in which there are convolutions, and in which there are nevertheless startling peculiarities for which we cannot account. The elephant carries an immense mass of matter—somewhere about three tons; but its brain is not more than three times the weight of the human brain.¹ Yet the elephant, with a brain only three times larger than ours, and with such an immense amount of bulk beyond ours, ranks very high in intelligence.² So that we are not to assume that size of brain, or quality, or number of convolutions, settles the whole question in regard to the scale of intelligence or mental power. The truth is, when we come to examine this subject in detail, we find so many abnormal facts which we are unable to classify, that we are left in very grave doubt at the end. It has been suggested, and the suggestion has some force, that the “elaboration of brain is connected with de-

¹ The brain of the whale is not more than twice the weight of the human brain, though the weight of the whale is sometimes sixty tons! The convolutions of the whale's brain are, however, very intricate.

² The brain of the elephant is, however, the largest animal brain known.

velopment of the muscular system."¹ There are many reasons that could be produced in support of that suggestion. The truth is, we are not yet furnished with definite data on which to base arguments whereby we may reach satisfactory conclusions. Even if we take for granted that the brain is the organ of mind, or, if you choose, that brain is mind, that hypothesis, if honestly applied, will be found to raise quite as many difficulties as it may seem to remove.

Then, besides, while admitting that the brain, or the nervous system generally, has a definite relation to mind and to mental action of different kinds, yet there are still some anomalous facts to be explained. If we take away the brain proper from a pigeon, we find that certain faculties remain; but the bird is unable or unwilling to originate action. It can see, and if you throw it into the air it will fly, but if it is not raised again after it reaches the ground it will make no motion; it will remain inactive and apparently stupid until it dies of starvation. If you press food into its mouth it will swallow it, but it will not collect food itself, though a plentiful supply of food be near. It will not originate action, but will direct motions given to it, to some extent. I do not suppose this experiment has ever been made on a human being, but there have been cases in which children have been born without this brain-mass, and have lived for some

¹ Calderwood's *Relations of Mind and Brain*, p. 206.

time. This cerebrum—according to our information gained from these experiments, or this pathological condition—is concerned in the *origination* of certain actions; but even such actions may be originated by impressions made from without, and various processes that ordinarily are largely under the control of the brain may be carried on in its absence.

While we speak correctly enough of the brain as intimately associated with sensation and intelligence, and while it is generally believed that the cortical¹ or outer substance has the closest relations with feeling and thinking; yet this brain substance may be removed in slices without pain, and even a large portion of one side or hemisphere of the brain may be injured or destroyed without any apparent loss of *mental* power.

The brain is a double organ, consisting of two hemispheres, united at the base by bands called commissures. Recently it has been argued by some that we have two brains; and it has been further maintained that from want of early training and development nearly one half of our brain power is unused. There are many curious and interesting questions raised by this hypothesis, on which my limits do not allow me to enter.

This, however, is certain, that the *mind relations* of

¹ The surface matter is called *cortical* because it resembles in position the *cortex* or bark of trees.

the brain are not the same as its *physical relations*. Dr. Ferrier calls attention to this in the following suggestive statement. "The physiological activity of the brain is not, however, altogether co-extensive with its psychological functions. The brain, as an organ of motion, sensation, or presentative consciousness, is a single organ composed of two halves; the brain, as an organ of ideation or re-presentative consciousness, is a dual organ, each hemisphere complete in itself. When one hemisphere is removed or destroyed by disease, motion and sensation are abolished unilaterally, but mental operations are still capable of being carried on in their completeness through the agency of the one hemisphere. The individual who is paralysed as to sensation and emotion by disease of the opposite¹ side of the brain (say the right) is not paralysed mentally, for he can still feel and will and think, and intelligently comprehend with the one hemisphere. If these functions are not carried on with the same vigour as before, they at least do not appear to suffer in respect of completeness."²

The truth is, the correlations of mind and brain are as yet untraceable. That there are decided and intimate relations between thought and nervous matter does not seem to be questionable. It

¹ The opposite side of the body is affected because the nerve fibres from each hemisphere *cross over* to the opposite side.

² *The Functions of the Brain*, p. 257. By David Ferrier, M.D. F.R.S.

can hardly be disputed that here we have reached a region where mind affects matter and where matter affects mind. Beyond this, however, we have not yet advanced. We are not able to group together any corresponding facts. In cases of mental unsoundness there are no invariable lesions of the nervous system to which we could refer errors in thought or feeling; and even if there were, it might be difficult to say whether they ought to be classed as causes or consequences. And, on the other hand, genius, or outstanding intellectual superiority, cannot be demonstrated by the scalpel or the microscope.

We may admit freely enough that the nervous system is the medium of communication between intelligence and matter. And this admission, I think, may fairly cover a large number of cases in which strange mental vagaries and freaks result from the condition and circumstances of the physical organism. As an illustration, and also because it is of practical significance and value, I may refer here to the action of alcohol on the brain.

When this poison finds its way into the blood it acts in a very decided and injurious manner upon nerve-tissues. It lessens their sensitiveness and dulls their action. The individual thus intoxicated or poisoned is less capable of directing his actions and doing what he ought to do, or even what he wishes to do. If the quantity taken be small, there may be only a blunting

of the fine edge of consciousness and right feeling. Of course, the effect produced is proportioned to the amount taken.

But when larger quantities are taken, there follows a very marked decrease of physical sensibility, accompanied with mental stupidity and decided loss of the power of moral self-government. Omitting further reference to its action on intelligence and conscience, let me speak only of its effect on sensibility. You remember that I formerly maintained that alcohol instead of increasing animal temperature actually lowered it, when taken in large doses. Yet any one might fairly have answered me then : "It may be true that the temperature of the body is lowered, judging by the thermometer ; but I know that if I take a sufficient quantity, although I have been shivering from the effects of external cold previously, I begin to feel quite comfortable, and this relief from the painful sensation of cold continues for two or three hours. How do you explain that?" Simply in this way. We have lowered our sensibility throughout. We have made ourselves to some extent incapable of appreciating the depressing action of the external atmosphere on our system. We have silenced the warning sentinels by sending them to sleep. Allow me to use a simple illustration. An old lady wishes to cross the street from the Bank of England to the Mansion House. She does not like the sights or sounds ; the driving to and fro of so many vehicles, the noise of

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the horses and the shouting of the drivers make her
timid and nervous. How can she get rid of these
causes of alarm? She puts one finger into each ear
and shuts both her eyes tightly, and commences to
walk across! That may make the transit comfortable,
but does it make it safe? That is precisely what we
do when we take alcohol. We dull our senses, and so
remove the discomfort; but we certainly do not raise
the temperature of the atmosphere that surrounds us,
nor do we increase our animal heat, we only lessen our
appreciation of danger, and thus facilitate and increase
our exposure to injury!

VII.

SPECIAL SENSES.

JOHN BUNYAN, in his story of the capture and recapture of the noble town of Mansoul, tells us that it had five gates: Ear-gate, Eye-gate, Nose-gate, Mouth-gate, and Feel-gate. And the late Dr. George Wilson, in a very noteworthy little book on the senses, makes use of the happy expression, "The five gateways of knowledge." It is by means of these inlets that we become familiar with the facts of the outer world. There are questions of a very interesting kind raised concerning the origin and nature of our knowledge. Some of you may be aware that for a long time it was held that all our knowledge was supplied by the senses. John Locke maintained that we gain knowledge by sensation and reflection. Liebnitz afterwards argued that there was nothing in the intellect but what was first in the senses, *except intellect itself*. And although it has been urged that this is a distinction without a difference, I am inclined to think that there is more in it than at first meets our sight. There is at all events a power to interpret and a power

to apply the information that we gain from without, that qualifies and conditions, to a very remarkable extent, the information itself. So far as our knowledge is concerned, it is quite evident that we are dependent on our senses to a very large extent, both for the nature and amount of that knowledge. Those who have been deprived of one or more of their senses have, in consequence, been shut out from a large mass of information with which we who are in possession of all our senses are familiar.

There is a very interesting account on record of Laura Bridgeman, who was thus afflicted, and of the means used for making her acquainted with the different facts and truths which she was unable to gain directly for herself.

We have noticed also that in cases where one or other of the senses has been lost, or is wanting, there is a special increase of power attainable by the other senses, so that the lacking information may be in some measure supplied. We are familiar with the fact that blind people, by means of their sense of touch, whereby they are even sensitive to slight movements of the air, can make themselves acquainted with a great many facts that we only recognise by means of vision.

Speaking generally, it may be asserted that our information of all things that happen without us is conveyed to us by means of these five senses. I am

not forgetful of the fact that we are not limited to them for our knowledge of sensations, or for our feelings. There are other sensations such as may arise, for instance, from pressure on the brain, or which may be caused by inflamed vessels of some of the deep parts of the body, or such general feelings of uneasiness as may result from fatigue after long-continued exertion. These are evidently internal sensations, and they are not conveyed to us through the channels of what we commonly call the five senses. But for our relation to the world without, and for our acquaintance with the facts it presents, we are dependent on the modes of access styled by John Bunyan, Eye-gate, Ear-gate, Mouth-gate, Nose-gate, and Feel-gate. It is of these five senses that I purpose speaking in this lecture.

For convenience of treatment and apprehension, we may begin with the simplest and ascend to the more complex. First, then, let me speak of TOUCH. This, unlike the other four, is not located in the head or face. We find that it is diffused, to a greater or less extent, over all parts of the body. A very interesting experiment has been devised for testing the amount of feeling in different parts of the body. A pair of compasses are taken with the ends somewhat blunted. The two points are applied to the skin in different regions. It is found that on the tongue we can distinguish the two points when they are very

close together; on the fingers we can only distinguish the two points when they are a little more widely separated, and on the back we cannot distinguish the two points until they are separated to some distance from each other. The amount of sensibility in different parts of the body can be determined with considerable accuracy by this experiment.

We know that generally the faculty of touch is exercised by means of the hand, and, more minutely, by means of the fingers of the hand. We can educate the fingers to a very large extent indeed, and can gain a vast amount of knowledge by their delicate discrimination.

Have you ever seen a sermon preached to people that were deaf? I ask, have you *seen* the sermon preached? because, although sermons are ordinarily heard and not seen, in this case the sermon must be directed to the eyes and not to the ears. The preacher must use his fingers instead of his tongue, and by means of these he must express all the ideas that are present to his own mind. I recollect seeing in an assembly of this kind—I cannot say audience—one woman who was blind as well as deaf. Now the question is: How could these words thus set forth on the fingers reach her mind, seeing that she had no eyes to see and no ears to hear? It was done very simply. Another of these deaf ones beside her took

one of her hands in her own, held it up, and made signs with her fingers on different parts of her hand, mainly on the fingers, corresponding to the signs made by the speaker (if I may call him a speaker), so that to this blind and deaf woman were conveyed, by means of touch, all the signs that were shown to the eyes of those deaf women who could see.

We can, in various ways, educate this sense of touch, and make it much more thorough and available for useful purposes. We find that those who are obliged to depend largely upon the exercise either of the eye or the ear, or it may be the tongue or nose, are able to train these organs to a much more acute sensitiveness than is attainable under ordinary circumstances. Of course that has its limits. We may so overwork or fatigue such an organ as the eye, as ultimately to render it unfit even for ordinary purposes.


- But under certain conditions of careful continuous exercise these sense-organs may become stronger and more skilful. An Esquimaux can detect a white fox in a snow-field; and a sailor can descry a sail on the horizon where the landsman sees nothing.

In touching, we bring any part of the fingers—say the point of the middle finger—into contact with the substance that we wish to examine, and we can then speak of its hardness or softness, its roughness or smoothness, or possibly its coldness or its warmth. We find that a very considerable amount of infor-

information concerning the qualities of the bodies that we touch enters by Feel-gate. We find it literally at our finger ends. Indeed, a very large amount of our knowledge in regard to the distance of bodies and in regard to the shape of bodies reaches us through the sense of touch rather than through the sense of sight. People who have been blind and who have subsequently gained the power of seeing have not been able in the first instance to determine the distance of objects; all things seem equally near, and there is no perspective; and there is reason to think that children, when they begin to use their eyes, have no ability to determine distances. Only when we bring in this faculty of touch to supplement the faculty of vision are we able to settle the relations and places that bodies occupy.

When we examine the skin we find a very peculiar arrangement on which this tactile sense depends. The nerves are distributed on the surface of the true skin, and are covered by the epidermis, or scarf-skin, which thus serves as a protection to the sensitive parts beneath. These nerves have, in certain parts, a peculiar arrangement called touch-bodies, in which we find a coil of nerve-fibre, and Paccinian bodies, which are like small seeds embedding the termination of the nerve in a soft substance.

There are in all these cases—and it is well to state it here and now—the terminal arrangement of the



nerve-fibre, where it makes acquaintance, so to speak, with the outer world; the nerve-cord, or conductor, along which the impression travels; and the nerve-centre, to which the impression being carried there results, somehow or other, a feeling or sensation. And do not let us forget this, that really lies at the basis of our study of all sensation; that we cannot pass by any effort of thought from matter as matter to sensation as sensation. The two things are distinct. We may, to a very large extent, make artificial imitations of different organs that we find in the body—say, for instance, imitations of the eye or ear. We can produce mechanisms adapted to receive light or sound; that is, to receive those vibrations of the atmosphere on which sight and hearing depend. I need not tell you, however, that these mechanisms are insensible. Except in the living body we have no sensation. Sensibility is peculiar to living, organised, bodies, and any descriptions of sight and hearing that leave this out of account, and are narrowed to the details of molecular or mechanical action, are deceptive and misleading. To such descriptions you must add the existence of a special faculty which is competent to translate in a fashion unknown to us, these vibrations of light or of sound into hearing and vision respectively.

In the simplest of all the senses, the sense of touch, we have ideas originated in consciousness somehow, by means of the contact between the exter-

nal organ of sense and the object that we are examining. The impression is propagated along the nerve-cord, and is translated somehow into sensation or feeling within our body, and, it may be, into an idea or recollection in our mind.

Let us next examine Mouth-gate. Here we find the tongue, which is commonly spoken of as the organ of taste. We are not to suppose, however, either that the tongue is confined to the task of tasting, or that this function is limited to the tongue. The human tongue may serve the highest ends in aiding to utter language the most ennobling; or it may give currency to words the most vile and degrading. If we examine the lower animals, we find that the tongue is, in many cases, the organ used for laying hold of external substances, and in some cases—in fishes, for instance—we find it has rows of teeth placed upon its surface, and it is intended, to a large extent, to operate in the work of primary digestion within the mouth. We find also that some animals use the tongue as an instrument for getting or grasping food. The ant-eater catches its prey by its tongue. We have the tongue used for a great many such purposes in other animals, indicating that it is not designed only and altogether as the organ of taste.

In man we find also that it assists in the process of mastication, rolling the food round and round in the mouth, bringing it into contact with the saliva, and

extricating any particles that may have got fixed among the teeth. Still it has a distinct use, along with other parts of the cavity of the mouth, such as the soft palate and upper part of the throat, in giving us what we call the sensation of taste. We find, just as in the skin, so in the tongue, there are *papillæ*—little elevations containing nerves that have this peculiar faculty of appreciating what we may term the sapidity, or tastefulness, of bodies.

We cannot taste any substance unless it is in a state of solution. I do not mean to say that all the substances we take into our mouth must be dissolved in liquid externally before we can appreciate their flavour. But they must be melted or dissolved within the mouth before they come into contact with these *papillæ* if we are to gain the sensation of taste. This does not, however, hold true with respect to gases. For instance, carbonic acid gas ordinarily gives no taste in the mouth. But if the tongue be dry, if the moisture be removed by any cause, and a stream of carbonic acid gas then plays upon the tongue, we find that we are now able to appreciate a distinct character or taste in the gas. But in dealing with substances generally, such as we use for food, their solution in the mouth, or before they are introduced into the mouth, is necessary, that we may be able to appreciate their taste. And I believe the tongue is placed in this position that we may form a fairly accurate idea

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the things that are good and the things that are bad before we allow them to pass further in. We give this organ to determine, to some extent at least, the fitness of the various substances we would introduce before permitting them to pass the barrier. Things that are unpleasant are generally to be rejected. I am afraid to speak very broadly or absolutely on this point, because I have a rational dread of my friends the physicians. They tell us that in some circumstances things that are very nauseous and disagreeable ought to be introduced into the stomach. But if you will allow me to talk of normal states and conditions of health, I think I may say that, under no limitation that I am acquainted with, the tongue determines with considerable accuracy, by its pleasure and satisfaction, those things that ought to be allowed to pass onward, and that its displeasure and dissatisfaction determine that those things which are disagreeable, just to the extent of their disagreeableness, are likely to prove injurious if they are allowed to go any further. We have naturally a tendency to reject any thing that is of this disagreeable character. It would be well—still speaking of ordinary cases, and not trenching on the province of our good friends the physicians—if we allowed that natural tendency and full play.

Right above Mouth-gate, we find Nose-gate, and its position indicates it is directly associated

tasting. Indeed, there are a great many things that we taste partly by means of these nerves in the tongue and mouth, and partly by means of the nerves of smelling in the nostrils. There are a great many things the savour of which we would not detect if we closed our nose tightly while holding them in the mouth. It is a very common practice when anything very disagreeable is being forced on children, to take hold of their little noses firmly, and to press the substance into their mouths, holding their heads well back, that it may find its way into their throat. The nose is placed right over the mouth that it may exercise a due amount of watchful care in this position. It is intended to be a sentinel like the tongue, and substances that have a disagreeable odour are to be shunned no less than substances that have a disagreeable taste. The nose is placed there for use, even though it may also be ornamental, and it is neither wise nor safe to neglect the intimations that it gives. Of course we may debase the sense of smell, just as we may debase the sense of taste, so that its likings become the reverse of right and natural. Many practices that are unnatural, and in the first instance abhorrent, may become habitual and pleasant. Some people acquire a taste for bitters; and others gratify their nostrils by huge pinches of *snuff*.² We may learn in various

² A good story is told of a Highlander, who offered his snuff-box to a gentleman who had a rather large proboscis, and who was in-

ways to like a great many things that are injurious, and even greatly to prefer them to things that are wholesome. But in the normal condition, if anything that is about to be introduced into the mouth has a disagreeable odour, we are disposed to accept the warning, and to reject the malodorous substance. There is special provision made in the construction of the nostrils for the appreciation of smells. Fortunately the nose is a very prominent feature in the face, and although we cannot take off the outer covering, yet a few words of description may convey a fair idea of its inner structure. We find it is divided into two cavities by a *septum*, or division, which is partly cartilaginous and partly bony; and each of these cavities is divided by a scroll-like bone² into three chambers lying one above the other. In the two uppermost the sense of smell resides; the lowermost being adapted, as we have formerly noted, for respiration. These bones are covered with mucus tissue, in which the filaments of the olfactory nerve are distributed.

The cavities of the nose serve also to give *timbre*, or resonance, to the voice, and when they are stuffed, as in catarrh, the voice becomes peculiarly flat and disagreeable. By this sense we are also warned when haling the balmy air of the Trosachs with widely-dilated nostrils. When the offer was rejected, somewhat disdainfully, with the explanation "I never take snuff," he turned away with the exclamation, "Mon, its a peety, for ye have *fine accommodation*."

² These bones are called the *turbinated bones*.

certain noxious gases are present in the atmosphere. The nerves of smell within the nostrils are branches of what is called the olfactory, and some twenty or more of these branches come down through a bony plate in the upper part or roof of the nose, which plate, on account of the numerous little openings through which these threads pass, is called the *cribriform*,¹ or sieve-like plate of the ethmoid bone. By this sense we detect and discriminate odours. These odours seem to be given off in a gaseous form; but it is puzzling to learn that one grain of musk can charge the atmosphere of a room for years without any appreciable loss of weight. When we desire to gain information in regard to the odour of bodies, we perform a process familiarly known as sniffing. We pull up the air into the nostrils several times, and there in the chambers of smell it is subjected to a close and keen examination.

The three senses of which I have now spoken are very much alike, and in some respects we may consider them modifications of the first sense—the sense of touch.

When we proceed to examine Ear-gate, we find that it has a very different construction. The simplest form of an ear, perhaps, is that which we find in the lobster. It has on one of its feelers a little bag of fluid, on the inner surface of which there is a nerve spread out which transmits impressions to a centre.

¹ Cribriform, from *cribrum*, a sieve.

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We find, as we ascend the scale of animal life, little hard, stony substances enclosed in this fluid-containing bag. The motions of these stones within the bag give more expressiveness and definiteness to the sounds by increasing the force of the vibrations. When we come, however, to man we find that the organ is much more complex. I need scarcely tell you in regard to the senses generally that we find other animals having much more acuteness in several of them than we possess. Not to speak of touch or taste—although I believe there are special differences in these also—we notice in the dog, for example, much more keenness of scent than we have ourselves. And in many of the uncultivated races who depend more upon their senses than we do who cultivate our intellects, perhaps to the neglect of the senses, we find appreciation of differences that are to us indistinguishable. Humboldt tells us that the Peruvian Indians can distinguish the different races from each other in a dark room: they can tell the different nationalities by the smell alone. We are told of boys who was, if I remember rightly, both blind and deaf who could tell his friends by their smell: we know that the dog can do this; it can trace its even through a crowded street. We know that Storchow can follow the scent can follow the scent prey for great distances. He does that by pu

nose down to the ground ; because animal effluvia of different kinds do not seem to be so diffusible in air as others ; they lie commonly near the surface.

So in regard to hearing, of which I am now speaking. There are great differences, even among men, as to acuteness of hearing. Some animals seem to have a wonderful power to appreciate and distinguish sounds at great distances. We ourselves know that when this faculty is cultivated—as it may be in certain directions—there is a large amount of interest and pleasure that may be gained. I am speaking now more particularly of our cultivation of this faculty in the appreciation and enjoyment of musical sounds.

When we investigate the structure of the human ear, we find it divisible into three parts—the external, the middle, and the internal. The external, which we can readily enough examine, seems to be adapted simply for the collection of sound, and is not so perfect in man as it is in many animals. They have external organs of hearing that are under the control of the will. They can bring these large lobes that we see lying on the side of their heads into different positions, best fitted for receiving such sounds as they wish to distinguish. We sometimes put our hand behind our ear in order to catch sound more accurately for discrimination, but in animals there is this special arrangement for the collection of air-vibrations.

A fair argument in favour of a backward evolution

has been raised in this connection. It is asserted that we have lost the power of moving the external ear through disuse.

If we follow the channel of the outer ear a little way in, we come to a membrane stretched across and closing the inlet, commonly called the drum of the ear—the *tympanum*. This membrane is very delicate, no thicker than gold-beater's skin, and therefore demands cautious treatment. It is very strong in proportion to its thickness, but it is quite possible to rupture it. People sometimes do so by introducing sharp-pointed instruments into the ear to remove the wax. A blow on the ear should never be given to a child, because this delicate membrane may be ruptured by the sudden compression of the air in front of it. Between this membrane and the inner part of the ear we have a space in which we find air, and at the other end of it another membrane, closing it in, and thus forming the true drum of the ear. We have two membranes, the outer called the *tympanum*, and this inner membrane, with the air between. We find also that there is a canal from the mouth to the middle cavity, called in books the eustachian tube or canal, and by this communication the enclosed chamber has an occasional communication with the outer air. You know that in drums, in order to produce sound from them, we must not only have parchment on both ends, but we must have a hole somewhere

allow transit of air. You cannot get the volume of sound without this provision. If I strike a tumbler so (standing in its natural position), I get sounds distinctly enough. But if I shut off the communication between the air inside and the air outside (inverting the tumbler), I get a very dull and imperfect sound.

Sometimes the (eustachian) tube ² or canal, by which this communication is maintained, gets blocked up, in consequence of what is commonly called a "cold in the head," and deafness results. This deafness disappears when the channel is again cleared. I may here give a hint that may be serviceable in certain circumstances. Possibly you have heard that when people go down in a diving-bell they suffer from a painful ringing and tightness experienced somewhere in this organ. That can be easily avoided by the action of swallowing frequently performed during the descent. For this little tube is opened in the process of swallowing. It is ordinarily closed, but when we swallow it is opened and shut every time. The pressure and pain result from the difference in density between the enclosed air and the air in the diving-bell; and the condition of the air within and without is equalised by freedom of communication.

Professor Tyndal, in his book on "Sound," states the

² The eustachian tube also serves as an outlet for any excess of fluid in the "drum."

fact to which I am adverting with his usual clearness: "The eustachian tube is generally closed, the air space behind the tympanic membrane being thus shut off from the external air. If, under these circumstances, the external air becomes denser, it will press the tympanic membrane inwards. If, on the other hand, the outside air becomes rarer, while the eustachian tube remains closed, the membrane will be pressed outwards. Pain is felt in both cases, and partial deafness is experienced. I once crossed the Stelvio Pass by night with a friend who complained of acute pain in the ears; on swallowing his saliva the pain instantly disappeared. By the act of swallowing the eustachian tube is opened, and thus equilibrium is established between the external and the internal pressure."¹

In the space behind the tympanum we find three little bones, called the hammer, the anvil, and the stirrup.² The relative position of these bones is subject to some alteration by the action of special muscles. I do not think that I can explain their action with any definiteness. Suffice it to say that they form part of the line of communication. It may be also sufficient to note that by means of this double membrane, forming the true drum, sound-waves are conveyed to the innermost part of the ear, called the labyrinth.

¹ Tyndal on *Sound*, pp. 71, 72.

² Malleus, Incus, and Stapes.

This is regarded as the essential part of the auditory apparatus, and it is conveniently distinguishable into three parts: the semi-circular canals on one side, the cochlea (shell-like cavity) on the other, and the vestibule between both. We might lose our way in attempting to explore this labyrinth, and the information attainable is scarcely definite enough to warrant the risk. So I shall content myself by stating that the nerves of hearing dip here into a jelly-like substance, the tremors of which, resulting from the vibrations that have been carried in, are in some manner conveyed to the nerve-centre. It is supposed that the nerves perform two separate functions, according to their respective positions and arrangements. The *vestibular* nerves are said to convey impressions of *quantity* of sound; and the *cochlear* nerves are said to distinguish *quality* of sound. We find at one place a great many thread-like fibres placed side by side with great regularity, and presenting the appearance of a key-board. These are called the fibres of Corti, and it has been suggested that they are like tuning-forks, each having been set to one note, and that their action determines our appreciation of musical intervals. Recent inquiries have not tended to confirm the probability of this suggestion. May I remind you, before dismissing this part of our subject, that sound depends on the vibration of the air. When a bell is rung the vibrations of the metal give rise to air-waves of definite dimension

which we recognise as sounds; but if the bell be placed in a glass vessel, from which we gradually withdraw the air by means of an air-pump, we find that although the ringing be vigorously maintained, the sound becomes fainter and fainter as the air becomes exhausted, until it ceases altogether. When we allow the air gradually to re-enter the vessel, the sound is renewed, and waxes louder and louder.

It seems wonderful—at least it does to me—that by means of these waves of air we have all the ideas communicated to our mind that are expressible, not merely by noises but by musical tones, and that thus also are awakened in us by these tones such a strange variety of emotions; and that undulations of air in the form of spoken words have such power to stir and stimulate thought, and desire, and passion. Much pleasant feeling is stirred in us through the medium of hearing. And to talk of this simply as a mechanical process, that can be explained in terms of matter, has always seemed to me one of the surest evidences of a shallow philosophy.

Over the other gateways of knowledge, Eye-gate may fairly claim pre-eminence. Its visitants come from near and far. Of all the senses it has the widest range. Our examination of it must, unfortunately, be far more brief than its importance warrants.

When we look upon each others' eyes, we notice that they are provided with what have been called

“shutters.” These shutters we close at night and open in the morning. Unlike other appliances of the same kind, these shutters are not only used to close the eye and prevent the entrance of light, they are also employed all day long in keeping the windows clean. We are winking consciously or unconsciously throughout the day, and every time we wink we bring down one of the shutters, with a fluid secreted on its surface, to wash the windows and to remove any specks or dust from its surface.

Looking into the eye, or rather looking at it from the side, you perceive that the front part of it bulges out somewhat like the glass of a watch. This, which is called the cornea, serves as a protective window to the eye, and is the transparent portion of a covering that goes round the whole eyeball, called the sclerotic coat or tunic.¹ Standing in front and looking through the cornea we notice a variegated curtain, not a curtain that falls, but a circular curtain that contracts or expands according to the necessities of vision. This is called the iris. Generally some one colour predominates—either blue, or grey, or brown—giving character and expression. Behind this circular curtain, which regulates the supply of light, lies the lens, in which the rays of light are collected and focussed. “We are most familiar with this portion of the eye as it occurs in fishes, looking in the recently-caught creature like a small

¹ From *skleros*, meaning hard.

ball of glass, and changing into what resembles a ball of chalk when the fish is boiled. This lens is enclosed in a transparent covering, which is so united at its edges to the walls of the eye that it stretches like a piece of crystal between them; and in front of it, filling the space dividing the lens from the watch-glass-like window, is a clear transparent liquid like water, in which the iris floats. The lens is further set like the jewel-stone of a ring, in what looks, when seen detached, like a larger sphere of crystal, but which in reality is a translucent liquid contained in an equally translucent membrane, so that the greater part of the eye is occupied with fluid; and the chamber, after all, which it most resembles is that of a diving-bell full of water. Lastly, all the back part of the eye has spread over its inside surface, first a fine white membrane, resembling cambric or tissue paper, and behind that a dark curtain; so that it resembles a room with black cloth hung next to the wall, and a white muslin curtain spread over the cloth. This curtain, or retina, seen alone, is like a flower-cup, such as that of a white lily, and, like it, ends in a stem, which anatomists name the optic nerve. The stem, in its turn, after passing through the black curtain, is planted in the brain, and is in living connection with it.”¹

The lens of the eye is not so convex behind as in front, and it is capable of being adjusted so as to

¹ Wilson's *Five Gateways of Knowledge*, pp. 13, 14.

increase or lessen its convexity according to circumstances; this power of adjustment, however, fails as we grow old. When we look into the eye through the lens it appears dark, because we are looking into a darkened chamber covered with a black wall-lining. This round dark central part of the eye is called the *pupil*, and, as you are aware, it is enlarged or diminished by the action of the circular curtain, the iris.

The iris, however, does not act independently; it takes its cue from the brain. We are consequently able to discover that the brain is injured or inactive, when we find that on flashing a strong light into the eye the pupil remains unchanged, the iris receiving no direction to close the gateway.

It may help us to appreciate the wonderful adjustments of the eye, if we consider what takes place in the studio of the photographer. In the photographic camera we have an arrangement for receiving the rays of light on a prepared sensitive plate. The exactness and definiteness of the picture depends on the proper adjustment of the lens to the position of the sitter: and when there is a large group of sitters it is found impossible to get them all into focus. The operator must manipulate skilfully and carefully to adjust the lens to the position the sitter occupies, so that all parts of the impression may be clear and distinct. So we adjust the lenses of the eye in gaining impressions of differently placed ob-

jects, only not so clumsily. Sometimes the photographer changes the position of the sitter, and sometimes he moves the whole apparatus that he is using. We, standing still, though not always without effort, can adjust the lenses of our eyes to the point of vision that we desire to reach. We do so partly by alteration of the lenses, increasing or diminishing the convexity of which I have spoken, and partly by change in the position of the lenses, brought about by the action of the muscles that rotate the eyeball. We have to remember, however, that any long-continued fixedness of the lens tends to give it a "set;" and we find that watchmakers and others who are constantly narrowing their vision to near and minute objects very materially lessen the range, and impair the usefulness of their eyes.*

Then, strangely enough, we find that at the very point where the optic nerve enters the eye there is absolutely no sensibility to light. Every eye has what is called a "a blind spot," and that blind spot is the

* Sometimes this lens becomes opaque, and then a "cataract" is said to have formed. In such cases the lens is simply extracted, and thus light again finds access to the retina. Formerly the cataract was *cocked*—that is, displaced from its position where it obstructed vision, but allowed to remain embedded in the other tissues. Occasionally a blow on the eye caused this displacement, and in such circumstances there would be the strange result of restoration of vision as a consequence of mechanical injury! Of course, in all cases either of removal or displacement of the natural lens, artificial lenses (spectacles) become necessary to secure definiteness of vision.

spot which of all others would seem most likely to be sensitive to light. A very simple experiment has been devised whereby we may recognise the absence of visual action at this definite part of the nerve.

If on a sheet of paper we mark a cross and a small black circle about an inch and a half apart, thus :



then closing the left eye and looking at the cross with the right, on gradually approaching the paper to the eye, we find that we reach a point at which the black circular mark becomes invisible; on either side of this point it becomes visible again. The point of invisibility marks the stage where the image falls on the entrance of the optic nerve. I need hardly say that this fact does not interfere with the actual usefulness of the eye.

At another point which marks the centre of the retina, we find what is called the "yellow spot," which is most sensitive to light, and which is thought to be chiefly employed in *direct* vision. Microscopical examination of these two spots reveals certain differences in minute structure.

There are two questions often asked that I shall not attempt to answer. How is it that with two eyes, instead of seeing double, we have single vision? And how is it that, although an *inverted* image is thrown on the retina, we see objects in their true position? Are not the needful hypotheses and ex-

planations written in the books of the physiologists? and may you not read there all about the other appendages and actions of the eye?

On the structure and function of all the parts concerned in the operation of the senses our knowledge has been amazingly increased by patient industry and detective instruments; but the very foundation of the bridge that crosses the chasm between physics and sensation remains yet to be discovered. We may tell how atmospheric waves may excite vibrations in various tissues; but how these vibrations are translated into sight and hearing passes our comprehension altogether.

"When I think, indeed," writes Dr. Wilson, "of that large-windowed little cottage which hides under the thatch of each eyebrow, and spreads every moment on its walls pictures such as Raphael never painted, and sculptures such as Phidias could not carve, I feel that it can with justice be likened to no earthly building; or if to one, only to that Hebrew Temple which has long been in the dust. Like it, it has its Outer Court of the Gentiles, free to every visitant, and its inner chamber, where only the Priests of Light may come; and that chamber is closed by a veil within which only the High Priest LIFE can enter, to hold communion with the spiritual presence beyond."¹

¹ Wilson's *Five Gateways of Knowledge*, p. 20.

VIII.

EVOLUTION AND APPLICATION OF ENERGY.


THERE is a story told of a Highlander who became, for the first time in his life, the happy possessor of a watch. He was never weary of applying it to his ear, and listening to its dulcet sounds. He would not part with it at any price. He thought it such good company that he took it to bed with him. In the morning, when he awoke, his first act was to lay hold of the watch and apply it again to his greedy ear. But alas! it was dumb. It emitted no sound. And our friend, as soon as he found an opportunity, parted with the watch for a trifle, rejoicing afterwards that he had got rid of it satisfactorily, because *it had died last night!*

We are sometimes told that the human body, like a watch, contains a certain amount of energy stored in it after the same fashion, and that it requires to have that energy restored over and over again by a process analogous to winding. We are informed that the human body, like a piece of mechanism, is fitted for performing a certain amount of work, and that energy

must in like manner be supplied to it in order that work may be done.

Now, on the present occasion we have to consider what I venture to call the *executive department* of the organism. We have looked at it broadly as a whole. I have endeavoured to outline for you the different parts of which it is composed. We have studied the "Commissariat," in the "preparation" and "conveyance of aliment;" and as an appendix I have spoken of "the removal of waste and noxious products." Then our attention was called to the "intelligence department;" and we have endeavoured briefly to glance at the "nervous system" and at the "special senses." We may now ask how the body acts; whence hath it the power that it manifests in living and in doing work? We have already learned that the body is developed from a germ; and we have learned also that all living matter comes from pre-existent living matter. In our study of *nature* we do not find any record of the *origination* of life. We cannot tell *how* life began, so long as we confine ourselves strictly to the investigation of *natural* facts. But we recognise life as energy, manifesting itself in various directions.

That I may not be misunderstood, allow me to say that I am not anxious to question current statements as to the present source of cosmic energy. I have no desire to enter the lists against those who maintain that force is centred in the sun, and that its various



manifestations are conditioned by its effluence from that unexplored body. But I remind you, that, in the first instance, going back to the beginning of vegetable life—and I do so because we are dependent on vegetable life for the maintenance of the animal life which we possess—we find that there are necessary, not merely the rays of the sun, meaning by that all that is contained in the force that is streaming from the sun ; but also something definite and real on the part of the living plant, whereby it is able to avail itself of this energy, and to build up into its substance the various materials that we find there. Allow me to remind you again that we are really dependent on the vegetable world for the supply of food. Of course carnivorous animals live on flesh ; but if we follow far enough back the course of feeding we come to those that feed directly either on the herbage grazed from the ground or on the fruit taken from the plant ; so that carnivorous no less than granivorous animals depend for supplies ultimately upon the vegetable kingdom. And the question is, Whence does the vegetable kingdom gain the power to store up in its structure matter in such form as to constitute it available nourishment for animals ?

We are told sometimes that this is determined by the *molecular machinery* of vegetables, that it is the molecular machinery of the cabbage or the pear tree, or of any other plant, that determines the particular form that the energy of the sun shall assume within

each individual organism. Now I confess I do not understand these two words, molecular machinery. In the first place, molecules are unknown to us. Sir W. Thomson says that if a drop of water were magnified so as to occupy a space equal to the earth—that is, were it enlarged to a diameter of 8,000 miles—a molecule of that drop would then occupy a space represented by something between a shot and a billiard ball. You can understand how infinitesimally small a molecule must be, when even in the magnifying of a drop of water to this immense extent, a theoretic molecule is so extraordinarily small as this illustration indicates. In fact, it is impossible to detect molecules by any microscopic power we possess; we believe that they exist, because the theory of their existence aids our conception of matter; but to reason from their existence and to base arguments on their mutual interactions, the present state of our knowledge does not altogether warrant. Then I take exception to the second word, machinery. That term has a very distinct meaning. We know what we mean by a collection of mechanism forming a machine or a mass of machinery. We find nothing like that in the living matter of vegetables. We find there, as I have often said, simple, clear, structureless matter that is possessed of the power of motion, and can change other materials that are supplied to it into forms similar to its own. We know of nothing corresponding to mechanism which

can account for the changes that take place within a growing plant. Yet we are asked to believe that by the aid of *molecular machinery* all these differences that are so easily recognised in the vegetable world are produced and maintained. This, however, I insist on as something that cannot be gainsaid, that we do not know that the sun possesses any power—no evidence of any sort is forthcoming to prove that the sun possesses any power—to raise matter from the inorganic state to the organic; to raise it from the condition in which we find it outside the living world into the condition in which we find it in a grain of wheat or any other living organism. In order to this raising from the lower condition to the higher there must be pre-existent life. There must be this vegetal power to avail itself of the sun's rays, to use the energy the sun supplies for the purpose of raising matter from the lower platform to the higher.

Now, in these circumstances to maintain that all life is inherent in the force of the sun, is to leave one of the principal factors in the problem out of account—the life itself—without which the sun's rays are powerless. I have spoken more than once of the transformation of energy and the conservation of energy. And we have heard a great deal about the dissipation of energy. Energy is the power of doing work. That exhausts itself in the performance of the work, and is thereafter to be sought under another form.

I admit, without questioning, all that is said by physicists in regard to this subject—the conservation of energy, and in regard to the other subject—the dissipation of energy, although I confess—probably it is because of my own dulness of comprehension—that I am unable to attain that measure of conviction and certainty in regard to some parts of these subjects which others seem to have reached. But I do not intend to contest any of the deductions that are prevalent in connection with this doctrine of the persistence of force, or that other doctrine of the gradual dissipation of force. You can find fuller information in regard to this matter in Grove's book on the *Correlation of Forces*. Professor Tyndall has published a lecture on *Force*,¹ in which, with some things to which I certainly object, there is a very large amount of valuable information. Perhaps a still more elaborate and satisfactory discussion of the subject may be found in Professor Tait's lectures on *Recent Advances in Physical Science*.

But without questioning or entering into any dissertations on force, I would suggest two cautions that to my mind seem to have considerable weight. The first is, that we are not to suppose that when it is admitted that there is a certain amount of energy existing in the universe, and that this amount of energy cannot be lessened or increased by anything that we

¹ Tyndall's *Fragments of Science*, vol. i. p. 421.

do, we are not to suppose that we have accounted for energy itself. Let us go back as far as we possibly can, not merely in history, but in thought, and let us endeavour to form a conception of *how* it was that energy came to exist within the bounds of this universe, and we will find that we cannot possibly account for it. The only admissible explanation seems to be that it was originally communicated (and indeed that it is still maintained) by some dominant will. I do not press this as a proof; but I contend that it stands alone as a rational theory. Science, at all events, is confessedly unable to account for the introduction, the origin, of energy. The question as to its beginning is one that cannot be answered; it is a problem insoluble by science. I know that it has been suggested that the great central source of energy, the sun, gained this power by the clashing together or coming together of a great many atoms of matter; and it has been suggested that the power in the sun may still be sustained by the falling into it of certain bodies, and by the force developed by their impact on its surface. It has been calculated that if we had a mass equal to the sun's mass, composed of the most combustible elements possible—those chemical elements from which the largest amount of heat can be evolved—we would only gain from its combustion a sufficient supply of such heat as we now have to last for 5,000 years. Consequently, as the sun has been giving a supply, according to the doctrine

of geologists, for a great many thousands, not to say millions of years, evidently this large supply cannot have been produced by the *burning* of any *known* substance equal to the mass of the sun itself. A mass of the most perfect combustibles we know *falling* into the sun from the earth's distance would yield an amount of energy equal to 6,000 times the resultant of its combustion. This, however, is *theoretical* explanation, fairly enough adduced, I admit, to account for the *supposed* fact; but even if it were demonstrated science it would not settle the question of the primary evolution of energy; it would only remove the investigation one stage farther back.

And this is the second caution. While I admit that I cannot lessen or increase the amount of energy existent in the world, and that no other person with whom I am acquainted has been able to increase or lessen it, I am not prepared to allow that it is *impossible* so to increase or lessen the amount of energy existent at any time. I believe that something came into the world that did not exist in the world previously when *life* began. I believe that something came into the world that did not exist in the world previously when *animal life* began. I believe that something came into the world that did not exist in the world previously when *rational life* began. Whether you can express these things in terms of motion or matter or not, these are things—powers I venture to call

them—that began to be, in a definite time, and they are real additions of some sort to the amount of existence and force on our planet. And if I believe, as I do, that there once lived on this earth a Man who could raise the dead, *then* there existed even on this planet power that could *give* energy, a Power that could impart force though we cannot, and that *could* have added in many directions, whether He did so or not, to the amount of energy existing in the world. And no one can deny that the Lord Jesus Christ *did* introduce into the world a real power, whether we call it spiritual or not, that is as fresh and inexhaustible to-day as it was 1800 years ago. And although this power has not removed material mountains, it has delivered men from spiritual death, and made them “a new creation,” qualifying them for doing deeds that were else impossible, and imparting to them another and higher life that nature can neither communicate nor explain.

I think it needful to give these cautions, because I quite apprehend the readiness with which any admission in regard to the amount of energy existing in the world—specially its persistence and unalterableness—might be used as an argument against the supernatural facts with which we, who are accustomed to read the Bible, are conversant. Indeed, John Stuart Mill admits that a miraculous event would not infringe the law of causation. In that case, he alleges, there would be pleaded fairly “a direct interposition of an act of

the will of some Being who has power over nature ;” and, he adds, “of the adequacy of that cause, if present, there can be no doubt ; and the only antecedent improbability which can be ascribed to the miracle is the improbability that any such cause existed.”¹ The truth is, if we admit the existence of the supernatural at all, we must recognise forces that are beyond the reach of physical science. Still, with these reservations, or rather, giving these cautions, I am ready to admit generally that the amount of energy in the world is fixed. I am ready to admit, further, that in an animal body such as ours a great part of the energy, at least, that we use—the greater part, perhaps the whole—is derived from the various foods that we assimilate. It would be rash to affirm that we find here an exclusive explanation of all the facts connected with the functions of the human body. For, if you remember, there are such things as bioplasts. We have made their acquaintance formerly, and we have not forgotten them. And when we talk about the food that we introduce into the body, and the oxygen that we receive into our lungs, and about all the actions that are carried on within the organism, we cannot forget that these bioplasts have a very intimate and peculiar connection with the whole process. We have, just as in the case of vegetables, this life conditioning the whole result. Therefore I object to saying

¹ *Mill's Logic*. Book iii. chap. 25, sec. 2.

that we have only chemical processes within the body, or that we have only mechanical processes, along with chemical, manifested in the human organism. We have something more and something other. And when we remember, moreover, that the bioplast precedes the food, we have a fact that qualifies our whole study of the subject. The bioplast is there in the first instance. In the case of the first life, the bioplast was there before the food: it was there to receive the food and to use it. And to leave out of account the fact that it is by means of this bioplast that the pabulum is made available, and that it is only made available by being transformed into its own likeness—taking on its own bioplastic character in living succession—to leave this out of account is to leave out a most important and essential fact in the whole history of life. It is the play of Hamlet, with Hamlet left out.

If it be remembered that we have food *plus* life, I have no objections further to offer to all that can be said in regard to the use of food for the maintenance of the animal, and for all the purposes to which force or fuel may be applicable in an ordinary machine. Nevertheless it is right to add that, although we can determine *quantitatively*, in arithmetical figures, the amount of work done as related to the amount of fuel supplied, in such a mechanism as the steam-engine, and can carefully and exactly measure both, we are

not able thus exactly and *quantitatively* to determine the relation between the food we introduce into the body and the amount of work that is done in the body itself. Indeed, we get into a new region entirely when we study living processes; and there is no subject that will give you more hesitancy, and on which there is greater uncertainty, in the writings of the best authors. It is extremely difficult to determine the relation between the food supplied and the work done. The reason is simple. We cannot follow the food in all the processes through which it passes, nor can we see the actions that take place in the whole current of the circulation through the body, or the decomposition of material or tissue afterwards in the production of the force that the body manifests. We must not suppose that there is anything like the same certainty or knowledge in regard to the transformation of food into animal force, that there is in regard to the transformation of fuel, in such a mechanism as the steam-engine, into the force that carries it along the rails and drags a number of waggons behind it. It is therefore misleading to argue as if the two transformations were identical.

Allow me to say here that it is admitted, looking at the human body as a mechanism for the production of forces, that it is the most economical mechanism that we know. It is certain that you can get far more from a ton of hay eaten by a horse than by its com-

bustion in the furnace of a steam-engine. And Helmholtz has made the calculation that only one-tenth of the fuel we use can be made available for mechanical work in our best machines; whereas the body can convert one-fifth of the power contained in food into an equivalent of work.¹ The living mechanism—I use the word freely because you cannot misunderstand it after my explanation; I do not like the word, but it is convenient—is so wonderfully complete, that we can, with the least possible loss, get from the food a very large amount of force. We have to take into account, in speaking of energy, that the body manifests not merely such power as is exhibited when I stretch my arm, or strike the table, or walk from one point to another. These are external manifestations. But there is energy expended also in the action of the brain, in the beat of the heart, in the expansion and contraction of the lungs, in the secretion carried on in the stomach and liver and in all other glands. Besides, there is continuous evolution of energy in

¹ We must distinguish, however, between economy of *force* and economy of *cost*. Letheby, in his *Cantor Lectures on Food*, says (p. 109):—"Taking a steam-engine of one-horse power (that is, a power of raising 33,000 lbs. a foot high per minute) it will require two horses in reality to do the same work for ten hours a day, or twenty-four men; and the cost would be 10d. for the steam-engine, 8s. 4d. for the two horses, and £2 sterling for the twenty-four men."

Donders has pointed out that the worst and most extravagant use you can make of a man is to employ him exclusively in mechanical work.

continually maintaining the temperature of the human body, which ranges between 98° and 100° Fahrenheit scale, with slight variations. As we know, heat is the outcome of energy, or rather, as is commonly stated in the present day, heat itself is a mode of motion. I presume that you have read or heard of the discovery made by Mr. Joule, of Manchester, as to the equivalent of heat in mechanical motion. He demonstrated that the exertion required to lift 772lbs. one foot high, or one pound 772 feet high, is exactly equivalent to one degree of heat on the Fahrenheit scale; or, conversely, what suffices to raise the temperature of a pound of water one degree can, acting otherwise, raise 772lbs. one foot in height.

The maintenance of animal temperature consequently indicates a very large expenditure of energy. For in the coldest regions, just as in the hottest—at the poles no less than at the equator—the human body maintains very nearly the same temperature. The Esquimaux and the Indian alike have a temperature ranging between 98° and 100° , and this temperature is sustained by the evolution of power from food available and applied to the production of heat. There are some terms employed in regard to this subject that it may be useful for you to remember. You will read in books about potential energy and active energy—energy of *position* and energy of *motion*. I shall endeavour to give you in very simple language an

explanation of what these terms mean.* Suppose we have 20lbs. of water lifted from the sea by the heat of the sun's rays. These 20lbs. are lifted up in the form of vapour, and they float in the sky at a certain height in the form of clouds. Then, through some alteration in the temperature, these clouds condense, and the contents fall as drops of water on the top of one of our highest mountains. In falling, these raindrops give out heat. There is heat given out in their condensation; but leaving that out of account, they give out heat when falling on the mountain summit. Then they give out heat as they roll down in the mountain torrent, and as they flow down in the stream or river until they reach the sea. It has been calculated that in the course of their descent from the cloud there is just as much heat given out as there was heat expended in raising them up in the form of vapour. The same amount of heat is evolved in their descent to that low level that was required to raise them to that high level. Take a more familiar instance. Two men are employed in raising a heavy weight until it reaches the height of twenty, thirty, or forty feet. When it has reached that height, by a special mechanism it is detached, and falls upon a pile fixed in the bed of a river. There is just as much force given out in its fall as

* For a clear and complete exposition of the "Doctrine of Energy," the student should consult Dr. Balfour Stewart's excellent little treatise, *The Conservation of Energy*.

there was expended in raising it up to the height. The force of its fall measures the force expended in raising it up to the height from which it fell. So in certain chemical combinations there is an amount of force stored up, and in the decomposition of these chemical substances there is as much force given out. We are all familiar with the fact that gunpowder explodes. By its explosion in a closed tube it is able to send a cannon ball or a rifle bullet with a certain amount of velocity to a definite distance. We have the force or energy stored up in the gunpowder communicating velocity to this ball or bullet. And we have the exact measure of the force in the gunpowder—taking other circumstances into account—determined by the velocity, the weight, and the distance. Now I suppose you are aware that gunpowder is a combination of nitrogen, carbon, sulphur, and oxygen. And in these nitrogen is the particular element which, apparently from its instability of chemical combination, is most available for the liberation of energy. We are familiar with the fact that cotton—a very innocent thing—when steeped in a nitrous solution, becomes tremendously explosive in the form of gun-cotton. A spark can at once set free its energy for the purposes to which we may wish to apply it. There are some substances that are even more easily decomposed, and from which we can liberate energy with more readiness than gunpowder or gun-cotton. For instance, chloride

or iodide of nitrogen, which a touch is sufficient to explode.

I allude to these things to illustrate the fact that in the materials of the body we have stored up a certain amount of energy that, because of the peculiarity of their chemical combination, can be readily liberated within the body for definite purposes and for definite work. You are aware that we take a very large amount of nitrogenous food—we are not forgetting the importance and value of carbonaceous food—and it is, to a large extent, these nitrogenous constituents that are serviceable within the body, very much after the same fashion that nitrogenous compounds are available outside the body for the evolution of force. Mr. Herbert Spencer, in his book on *Biology*, insists very strongly, and I think very fairly, that we have in the nitrogenous alliances a very large amount of force or energy stored up that can be liberated *readily* and *easily* for the doing of work. How the various elements are combined in the body, and in what precise circumstances they are usefully decomposed, has not been at all definitely ascertained. It was at one time thought that muscles, for instance, in being exercised are decomposed, and that by the destruction of the muscle the power of doing work resulted, that every time I strike the table, or walk from one point to another, muscular tissue is consumed in the production of motion and heat that follow. But Mayer has

given good reasons for supposing—and his conclusions have been strengthened by subsequent experiments—that it is not by the decomposition of muscle, but by the supply of blood to the muscle, that force is evolved.¹ I am not going to enter upon that matter; I wish merely to call your attention to the fact that, although we know that different substances are capable of being decomposed, after they have passed through living processes within the body, we are not able at this moment to say, exactly, in what precise circumstances this destruction of compounds takes place for the liberation of force. Still, we know that it is by the falling of this compound down to a lower level—if you will allow a metaphorical expression—that we have force produced. As by the falling of a mass of water (raised by the sun's rays from the level of the sea) down from the mountain top to the level of the sea again, a large amount of work may be done—a great amount of solid material carried down, many mills turned, and a great many useful mechanical purposes served—so in the falling down of chemical compounds from the high condition which they have reached in combining, to a lower condition, a large amount of power may be given out that may be turned to useful purposes, such as the production of heat, or the performance of work.

¹ Mayer in 1845 maintained that "a muscle is only an apparatus by means of which the transformation of force is effected; but it is not the material by the change of which the mechanical work is produced." He regarded the blood as "the oil in the flame of life."

I think I have said enough to explain how, according to our present knowledge, we believe that this energy is liberated within the body. It comes from the transference of this matter, in the higher condition to which it has been raised through the processes of life, down to the lower condition in which it ceases to be serviceable for the interests of the body, and is either turned out of the body or is sent back in the current, to be again submitted to a similar process that will raise it up anew to the higher condition that it may fall another time. So that, in a real sense, stores of energy are supplied to the body from day to day. The body is *wound up*, metaphorically, by the food that we take ; the body may be described as being fed with fuel, like the furnace of the steam-engine. Only, in addition to what I have already said about bioplasts, and about the action of life generally, there is this to be taken into account : that not only are these materials raised up to a certain condition before they are available for us, but they are raised still further within the body by the processes to which they are subject in the organism itself. I have seen the matter put in this form. Suppose we have three steps or platforms : a lower representing inorganic material ; a second, say a foot higher, representing the vegetable plane ; and a third, a foot higher still, representing the animal plane ; then from the highest platform the fall of a body down to the lowest, of course, develops more force than the

fall of a body from the middle platform to the lowest. The fall of a body from the height of the table is of course productive of more heat, by its impact with this platform, than the fall of a body from half that height ; that is to say, there is more potential energy (energy of position) in a body placed higher up than in a body at a lower level ; there is more energy that can be exercised, and is actually exercised (energy of motion), when it falls. The potential energy is that which it has when raised up, like a mass of matter on the table, or like the rain in the clouds. The active energy is that which is manifested in its fall to the lower level. From whatever source it may be derived, it is evident, from the organic processes to which it is subjected, that all the food we take is raised to this highest platform, and so made fully available by energy of position for evolution of energy of motion. When it is so raised, we set it free by means of nervous action. I explained that on a former occasion. The nerve-cord conveys the impulse causing the muscle to contract. The power is developed in the muscle, but the stimulus that determines the exercise of this power is conveyed by the nerve from the nerve-centre.

Here we are confronted with another question. Whence does the impulse ultimately issue ? If I will to walk or raise my hand, of course the nerves stimulate the muscles, and they obey, and energy is liberated. But whence, first of all, comes the force, impulse, in-

tention—call it what you will—that, carried by the nervous system, sets free this energy? A plain man will answer, "From myself." Interrogated further, he will explain that he means from his mind or will. And our wisest scientists cannot say anything other, or more profound. Some, indeed, affirm that this is poetry, but I maintain that it is the simple utterance of conscious fact, which is as real to me as any fact can be to which my senses testify. I know that, if I wish or resolve to perform any action that is within the limits of my capacity, so soon as I have formed the wish and determined the deed, the deed is done. There is a bridge crossed immediately between this intangible thought or purpose in my mind, and the brain or nervous system whereby the material framework in all its parts is governed and controlled. And it is impossible to talk of this command issuing except in terms that personify. Our most determined materialists are betrayed into talk of engineer or driver, or director or somebody else at the head of affairs that gives impulse and counsel, and determines all the subsequent action. They must poetise. They cannot escape the practical, powerful influence of consciousness, whereby they are inexorably reminded that there is behind and above the brain a mysterious power that bridges over the gulf between itself and matter, and acts effectively on the organism for the promotion of such ends as it may desire to reach. The laws and limits of thought and

language *bar even the statements* of a consistent materialism.

" Strive to expel strong Nature, 'tis in vain ;
With double force she will return again." †

† " Naturam expellas furcâ, tamen usque recurrit."—*Horace*.

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